Stanley Baker

SALEM LAKES

LAKE LAY MONITORING PROGRAM

1983

Freshwater Biology Group (FBG)

University of New Hampshire

Durham

by

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PREFACE

A non-technical, comprehensive summary begins the report. The summary is intended to provide a quick reference to the main findings of the study. The reader is referred to Appendix B and the glossary for a clarification of technical terms and concepts.

ACKNOWLEDGEMENTS

1983 is the third year Salem has been been a participant in the Lake Lay Monitoring Program. Under the direction of Mr. Gary Wright, LLMP has continued strongly in Salem. Lay monitors in Salem included:

Arlington Mill Resewoir

Site 1, 2, 3 -- Dot Smeltzer, Jodi, Chris, and Paulette.

Canobie Lake

Site 2 -- Butterfield and Wright

Site 3 -- Wright

Captain's Pond

Site 1 -- Tom McGrath

Millville Lake

Site 1, 2, 3, 4 -- Chuck Stewart and Chuck LaRoche

Shadow Lake

Site 1 and 2 -- Peter Jeans

We congratulate the lay monitors on the quality of their work, and anticipate that they will continue with the program next year. We also express our appreciation to Mr. Wright and all the other members of the Salem group for their time and effort. Also, we thank everyone who provided boats for our visiting team.

Members of our Freshwater Biology Group field team included Kim Babbitt, Dan Hayes, Wayne Boisselle, Tom Balf, and Mike Martin. Dan was team leader, and was responsible for coordinating all data analysis and interpretation. He and Tom were the zooplankton experts. Mike was the phytoplankton expert. Kim and Wayne specialized in phosphorus and chlorophyll <u>a</u> analysis. All members of the team helped in data organization and filing. Also, all team members participated in field trips throughout the summer.

This report has been produced in large part with data management and word processing programs on the UNH DEC-10 computer. Graphics were produced with program UPLOT and the CALCOMP drum plotter available on the DEC-10 system. The Office of Computer Services kindly provided computer time and data storage space for the Lake Lay Monitoring Program.

INTRODUCTION

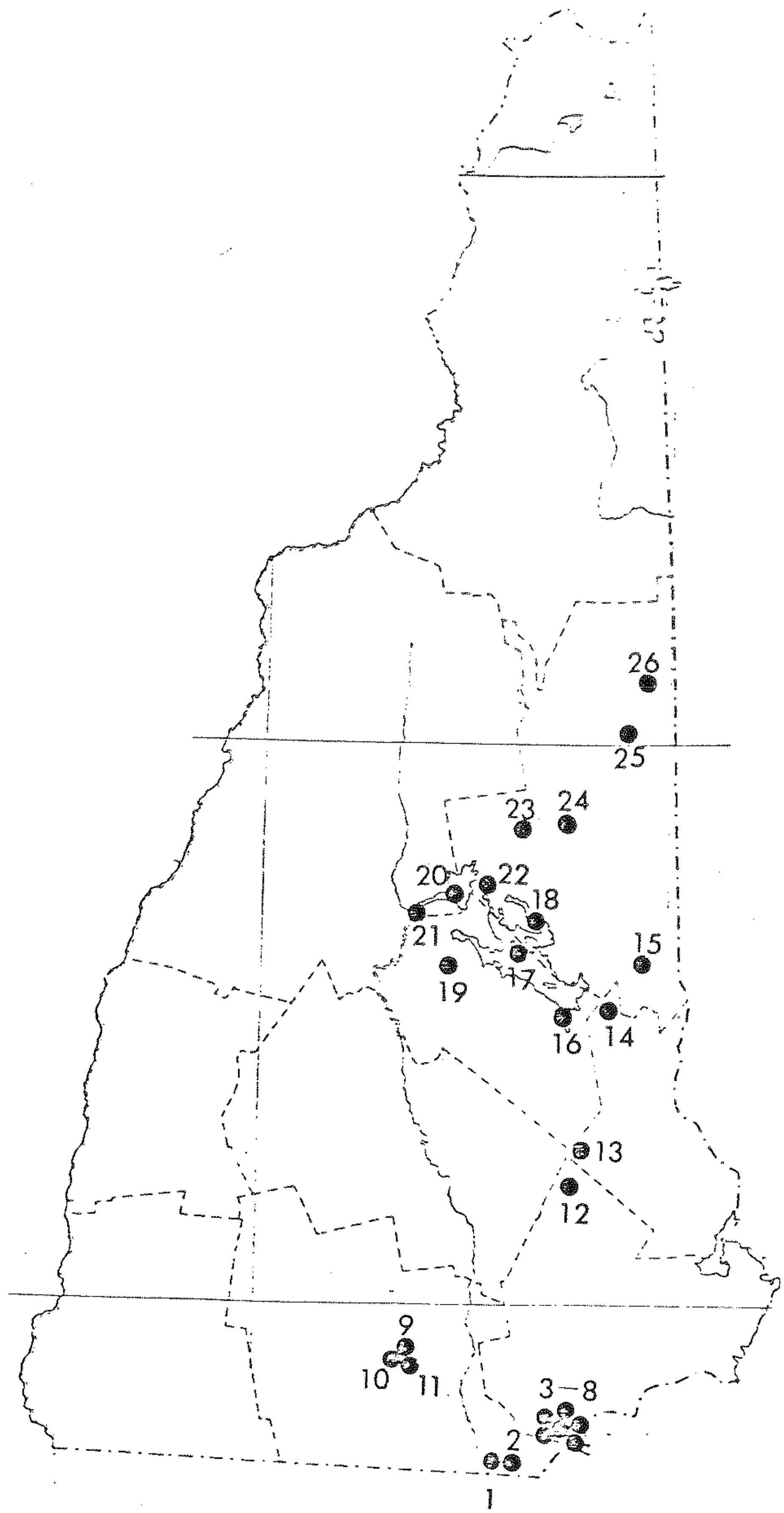
This report presents the finding of the 1983 summer study of Millville Lake, Arlington Mill Reservoir, Captain's Pond, Shadow Lake, and Canobie Lake. The study was conducted jointly by the Freshwater Biology Group (FBG), University of New Hampshire, and by the Town of Salem, as part of the Lake Lay Monitoring Program (LLMP). The LLMP is a long-term water quality monitoring program that relies heavily on the efforts of lay persons. In Durham, the LLMP is conducted by Dr. Alan L. Baker (Associate Prof. of Botany) and Dr. James F. Haney (Associate Prof. of Zoology), who direct a team of trained graduate and undergraduate students. Space and research facilities were provided by the Departments of Botany and Zoology at the University of New Hampshire. Secretarial services were provided by the Department of Zoology.

The LLMP is a cooperative effort between the FBG and cooperating lake associations, conservation commissions, and municipalities. Funding for the program is derived solely by contributions from the participating groups. During 1983, the participating groups included: Walker Pond Protection Association, Town of Hudson, Town of Salem, Town of Merrimack, Town of Amherst, Lake Chocorua Conservation Federation, Winona Lake Association, Lake Winnipesaukee Association, Squam Lake Association, Merrymeeting Lake Association, Pleasant Lake Association, Lake Association, Bow Lake Association, and Kanasatka Lake Association.

The LLMP has two major goals: first, to carry out scientific investigations on participating lakes in order to provide a data-base on lake biology, physics, and chemistry; and second, to educate people about lakes and their management. A broad data-base on lakes is necessary for their proper management, but is often lacking. Through the efforts of lay monitors and FBG members, such a data base can be provided. This commitment is long-term due to the long period of time it may require a lake to exhibit signs of disturbance. Continued monitoring from year to year is essential for the early detection of changes in lake conditions.

Education is also an important goal of the LLMP. Through education, people's awareness of lakes and human activities that may influence lakes is heightened. Perhaps the saddest occurrence is when a lake's quality is severely degraded without anyone aware of the fact, or worse yet, not caring.

Figure 1. Map of New Hampshire showing lakes involved with the LLMP.



Key to Figure 1: Lakes previously or presently in the LLMP of New Hampshire.

Map Location	Lake Name	Number of FBG Observations	Number of Lay Observations
1	Ottarnic Pond	11	37
2	Robinson Pond	10	79
3	Arlington Mill Resevoir	20	78
4	Canobie Lake	15	29
5	Millville Lake	10	84
6	Shadow Lake	9	17
7	World's End Pond	0	12
8	Captain's Pond	0	7
9	Naticook Pond	2	9
10	Horseshoe Pond	0	14
11	Baboosic Lake	11	48
12	Pleasant Lake	6	72
13	Bow Lake	2	0
14	Merrymeeting Lake	12	58
15	Lovell Lake	2	0
	Lake Winnipesaukee		
16	Alton Bay	2	85
17	Long Island	0	38
18	Moultonborough Bay	26	172
19	Winona Lake	4	4
20	Squam Lake	18	358
21	Little Squam Lake	14	76
22	Kanasatka Lake	0	3
23	Bearcamp Pond	7	86
24	Silver Lake	2	50
25	Lake Chocorua	9	16
26	Conway Lake	5	28

Brief Non-technical Summary

1) The water quality in the Salem lakes ranges from 'good' in Canobie Lake, to 'fair' in Shadow, Arlington, and Captain's, to 'poor' in Millville. This classification is based primarily on the average water transparency, and the amount of algae present in the water.

2) No trends are apparent in water quality in the Salem lakes. Gradual changes in water quality may be taking place, but year to year differences in weather and variation in the measurements require longer monitoring to detect slow changes.

4) Despite some of low pH values, alkalinities were moderate and should provide some resistance to acid rain.

5) Salt and chloride concentrations are higher on the average than many of the other lakes in the LLMP. This is probably due to inputs by road salt, and/or sewage.

6) The water quality of Shadow, Captain's, Arlington, and Millville Lakes might be improved if some of the nutrients entering the lake could be controlled. As a first step towards this goal, a program of phosphorus sampling is recommended to detect the locations and probable sources of this nutrient.

Comments and Recommendations for the Salem Lakes 1983

1) The consistency of data collection from the lay monitors was excellent on Arlington Mill Reservoir. Millville Lake was also well covered during July and August. The other lakes however, were covered less well seasonally. It must be emphasized that to accurately detect and record changes in water quality from one year to the next, seasonal coverage must be as complete as possible.

2) In order to ascertain the effect of dissolved color on Secchi disk depth, lay monitors should also collect samples for analysis of dissolved color, utilizing the water that has passed through the filter while taking the chlorophyll sample. Arrangements should be made as early as possible in order to allow full seasonal coverage.

3) The mesotrophic condition of Shadow, Captain's and Arlington and the eutrophic condition of Millville is very likely caused by an excess of nutrients such as phosphorus entering the lake. The experience from many other lakes in the country indicates water quality is often rapidly improved if reductions can be made in the loading of these 'limiting nutrients'. Thus, we recommend that the Salem Lakes LLMP group initiate a phosphorus sampling program to determine the major sources of nutrients into each lake. From this information is can be decided which sources of nutrients can be most easily regulated.

Executive Summary for Salem Lakes 1983

1) Canobie Lake is the most cligotrophic, with a chlorophyll *a* concentration averaging 1.1 mg/cubic meter for the summer. Canobie had the deepest average Secchi disk depth (6.2 meters). The other four lakes would be classed as mesotrophic based on chlorophyll *a* and Secchi disk depth. Arlington is the least productive of the fcur, with an average chlorophyll *a* concentration of 3.7 mg/cubic meter. Millville and Shadow were very similar on the basis of chlorophyll *a* with average concentrations of 4.0 and 3.9 mg/cubic meters respectively. Millville, with an average Secchi disk depth of 2.0 meters was substantially less clear than Shadow with an average Secchi disk depth of 3.2 meters. Captain's Pond had the highest average chlorophyll *a* with 4.2 mg/cubic meter, but this may be due to the later start their group had in the 1983 season. The average Secchi disk depth at Captain's Pond was 3.3 meters.

2) The lowest concentrations of total phosphorus were in Canobie with an average of 9.0 micrograms per liter. Arlington had moderate concentrations with 15.6 micrograms per liter. Millville had a higher total phosphorus concentration with 19.6 micrograms per liter. Shadow had the highest total phosphorus concentrations with 21.2 micrograms per liter. Except for Canobie, these lakes would all be classed as mesotrophic based on total phosphorus concentrations.

3) Based on phytoplankton counts, all five lakes can be classified as mesotrophic. Arlington had the lowest density (813-935 cells/milliliter) and Millville and Shadow had the highest densities (1001-1532, and 1524 cells/milliliter). Canobie also had a surprisingly high density of phytoplankton, with 946-1033 cells/milliliter. The species composition of all lakes was indicative of mesotrophic conditions. All had some species indicative of mesoptrophic or eutrophic conditions. Millville had the highest density of herbivorous crustacean zooplankton, with an average of 65 animals per liter. Next was Shadow, with 15 animals per liter, Canobie with 12 animals per liter, and finally Arlington with 8 animals per liter.

4) The Salem lakes have greater resistance to acid rain than many lakes in New Hampshire, due to their higher alkalinities. Average alkalinities were in the range 12.9-17.3 milligrams calcium carbonate per liter. Low pH values were measured in Canobie and Arlington however.

5) Dissolved oxygen concentrations in the hypolimnion fell below the tolerance level for fish in all five of the Salem Lakes except Millville. The rate of decrease in oxygen indicates moderate productivity.

6) The specific conductivity was relatively high in all five lakes (94.1-161.2 micromhos per cm), as was the chloride ion concentration (14.6-29.2 parts per million). This indicates that inputs of road salt and/or of sewage are significant.

METHODS OF LAY MONITORS

Lay monitors collected data on three parameters: thermal stratification, water clarity, and chlorophyll <u>a</u> concentration. Data were collected at weekly intervals whenever possible.

Thermal profiles were obtained by collecting lakewater samples at several depths with a modified Meyer bottle (Lind, 1979). Samples were obtained by lowering the empty but weighted bottle and sampling (by pulling out the stopper) at 1-meter intervals. The temperature of the samples was measured with Taylor pocket thermometers, and recorded in degrees Celsius.

Water clarity was measured while lowering an 8-inch (20 cm) Secchi disk and holding a view-scope just below the surface to eliminate the effects of surface reflection and wave-action. When the Secchi Disk disappeared the depth mark on the plastic suspension line was noted. The disk was raised until it just came into sight, and again the depth on the line was noted. The process was repeated two to three times, and an average between the two marks on the line (the point of disappearance and the point of re-appearance) was considered to be the Secchi Disk Depth (SDD), measured to the nearest one-tenth meter (0.1 meter) -- as for example, 5.2 meters. Readings were generally taken between 9 a.m.

and 3 p.m., the period of maximum light penetration.

Chlorophyll a concentration was used as an estimator of algal biomass. A weighted tube 33 feet (10 meters) in length was used to collect an integrated water sample from the 'upper-lake' (epilimnion). The weighted end of the tube was slowly lowered to the interface of the epilimnion and the 'middle-lake' (metalimnion). The end of the tube was then bent double to shut off flow of air and water, and the weighted end of the tube (presently at the base of the epilimnion) was pulled up to the surface with a plastic line attached to it. The water in the tube (epilimnetic lakewater sample) was poured into a plastic bottle by placing the weighted end of the tube into the neck of the bottle and, while keeping the bent-off end above the weighted end, unbending the upper end (allowing the sample to discharge into the bottle).

Water samples were filtered through a membrane filter with a porosity of 0.45 microns. The damp filters containing chlorophyll-bearing algae were air dried for at least 15 minutes to prevent decomposition. Filtration and drying were done in the shade to minimize destruction (by bleaching) of chlorophyll. The dried filters were then sent to UNH for analysis. [In Durham, members of the Freshwater Biology Group extracted chlorophyll in 90% acetone saturated with magnesium carbonate, and read the absorbance of the sample at standard wavelengths (663 and 750 nanometers). If sufficient pigment was present, the sample was acidified and reread to enable estimation of the percentage of active chlorophyll relative to the sum of the pigment plus all of its breakdown products that were present.]

METHODS OF FRESHWATER BIOLOGY GROUP (FBG) TEAM

The same as well as additional parameters were investigated by the FBG research team. The additional factors were primarily measurements of sunlight penetration into the lakewater, and water chemistry. The latter included dissolved oxygen, 'free' (unbound) carbon dioxide, pH, specific conductivity, chloride ion, and total phosphorus. In addition, the microscopic plants (phytoplanktonic algae) and animals (zooplanktonic invertebrates) were identified. Relative or absolute counts were made.

Dissolved oxygen and temperature were measured with a Yellow Springs Instruments Model 54A Oxygen/Temperature meter with a submersible probe. Readings were taken at 1-meter intervals throughout the 'upper-lake' (epilimnion) and 'lower-lake'(hypolimnion), and at half-meter intervals through the 'middle-lake' (metalimnion).

Sun- and skylight penetration into the lakewater was measured at 1-meter intervals with a Whitney submersible photometer model LMA-8A, and the relative light intensity was recorded. Measurements were taken on the sunny side of the boat.

Dissolved water color was measured by reading the absorbance of filtered lakewater (0.45 micron) at 440 and 493 nanometers, in a Bausch and Lomb Spectronic 710 with a path length of 15 cm.

Water chemistry (alkalinity, free carbon dioxide, pH, and specific conductivity) samples were collected with a 3-liter Van Dorn bottle. Samples to be analyzed for alkalinity, free carbon dioxide, specific conductivity, and pH were stored on ice in 250 ml polyethylene bottles.

Alkalinity, free carbon dioxide and pH were determined in the field, within 1 to 2 hours of sampling.

Alkalinity was determined titrimetrically with 0.002 N sulfuric acid to a final pH of 4.5, with a combination solution of the two dyes bromocresol green and methyl red as the end-point indicator (E.P.A.,1979). Alkalinity is expressed as equivalents of calcium carbonate.

'Free' (unbound) carbon dioxide concentration was determined by titrating the fresh lakewater samples with 0.0027 N NaOH to a final pH of 8.3, and with the dye phenolphthalein as the end-point indicator.

pH was measured with a pH meter (Corning Model 10) equipped with a combination probe (Orion Co.).

Specific conductivity was measured with a Barnstead Conductivity Bridge Model PM-70CB equipped with model B-10 probe (cell constant = 1.0). Correction for sample temperature was made with a standard curve.

Chloride ion concentration was measured with a pH meter (Corning Model 10) equipped with a chloride electrode (Orion model 94-17B) and a double junction reference electrode (Orion Model 90-02). Standard curves were prepared every 2 hours during laboratory analysis.

Samples to be analyzed for total phosphorus, phytoplankton, and chlorophyll a were collected with a vertical 'tube' sampler. Chlorophyll a samples were filtered, dried and analysed in the same manner as those collected by lay monitors.

Total phosphorus samples were stored in acid-washed 250 ml polyethylene bottles, and were fixed within 1 to 2 hours with 1.0 ml concentrated sulfuric acid. In their Durham laboratory, the FBG members digested the total-phosphorus by adding ammonium persulfate and autoclaving the samples for at least 45 minutes. Finally, the phosphorus content of the samples was analyzed with the single-reagent method that included a fresh solution of ascorbic acid and potassium antimony tartrate (E.P.A., 1979). Absorbance of the blue phosphorus complex was measured spectrophotometrically at 650 nm.

Phytoplankton samples were fixed with iodine (Lugol's Solution) in the field, within 1 to 2 hours after collection. Phytoplankton were counted with a Unitron 'inverted' microscope after settling the samples for 24 hours in counting chambers. At least 200 individual algal 'units' were counted with a modified scan technique (Baker 1973).

Zooplankton density was estimated in samples collected by towing up a plankton net (30 cm diameter, 150 micron porosity) through the oxygenated (>0.5 ppm) portion of the lake. Samples were fixed after collection with a 4% formalin-sucrose solution (Haney and Hall, 1973), and subsampled with a 1-ml Hensen-Stemple pipet. Sufficient subsamples were taken to insure that at least 100 microcrustaceans were counted.

RESULTS AND DISCUSSION OF LAY MONITOR DATA

Lay monitor research was conducted separately from Freshwater Biology Group (FBG) research, thus the results are presented separately. Three sampling sites were active on Arlington Mill Reservoir, four on Millville Lake, two on Shadow Lake, one on Captain's Pond, and two on Canobie Lake (Fig. 2, 3, 4). The lay monitor raw data for summer 1983 are presented in Appendix A.

Lay monitors collected information on three parameters: water transparency (Secchi disk depth), productivity (chlorophyll a), and thermal stratification (temperature profile). Information on thermal stratification is used mostly to determine the depth of the chlorophyll a sample. The lakes were stratified during the majority of the testing period (June-August), although some sites were not stratified on all test dates. Signs of destratification were evident during late August and early September.

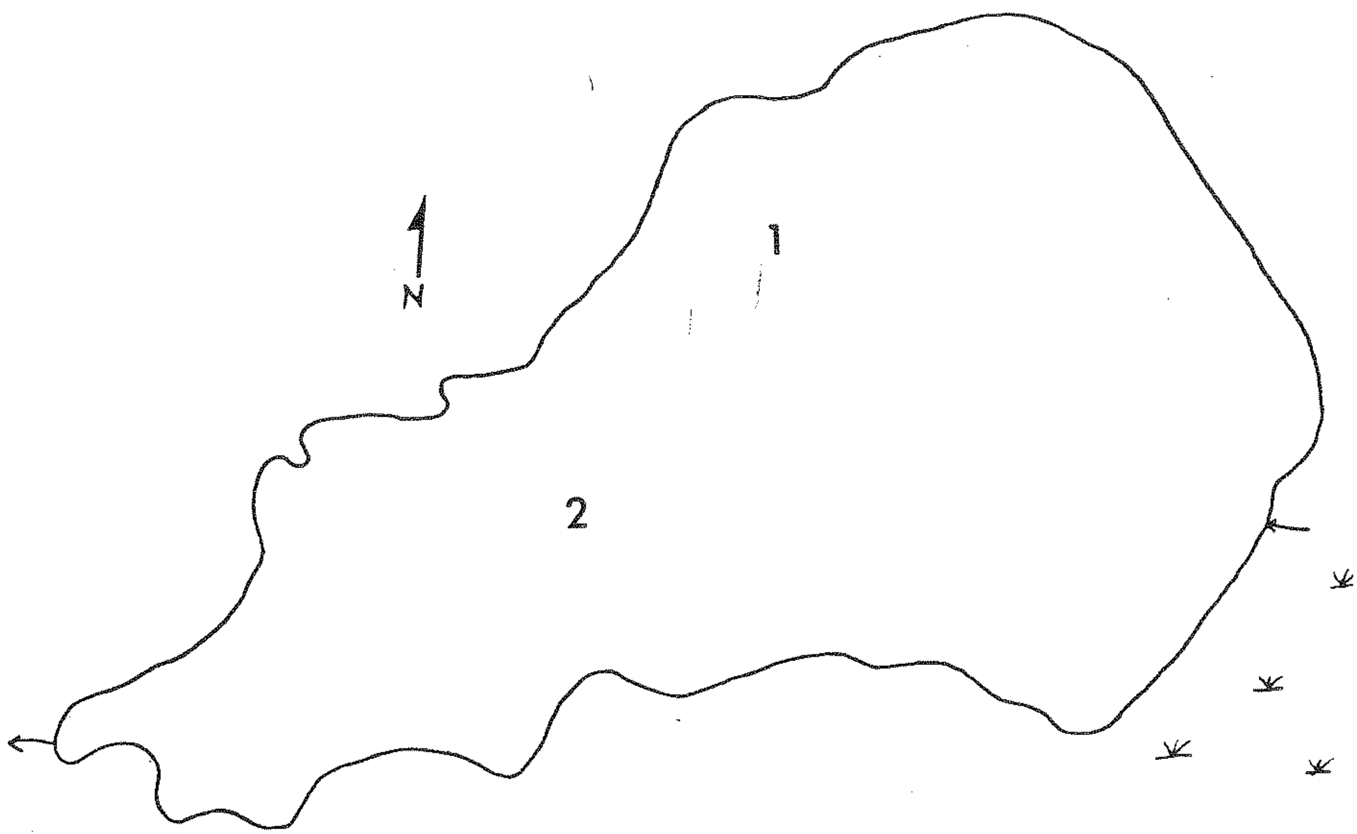


Figure 2. Captain's Pond, Town of Salem, New Hampshire.

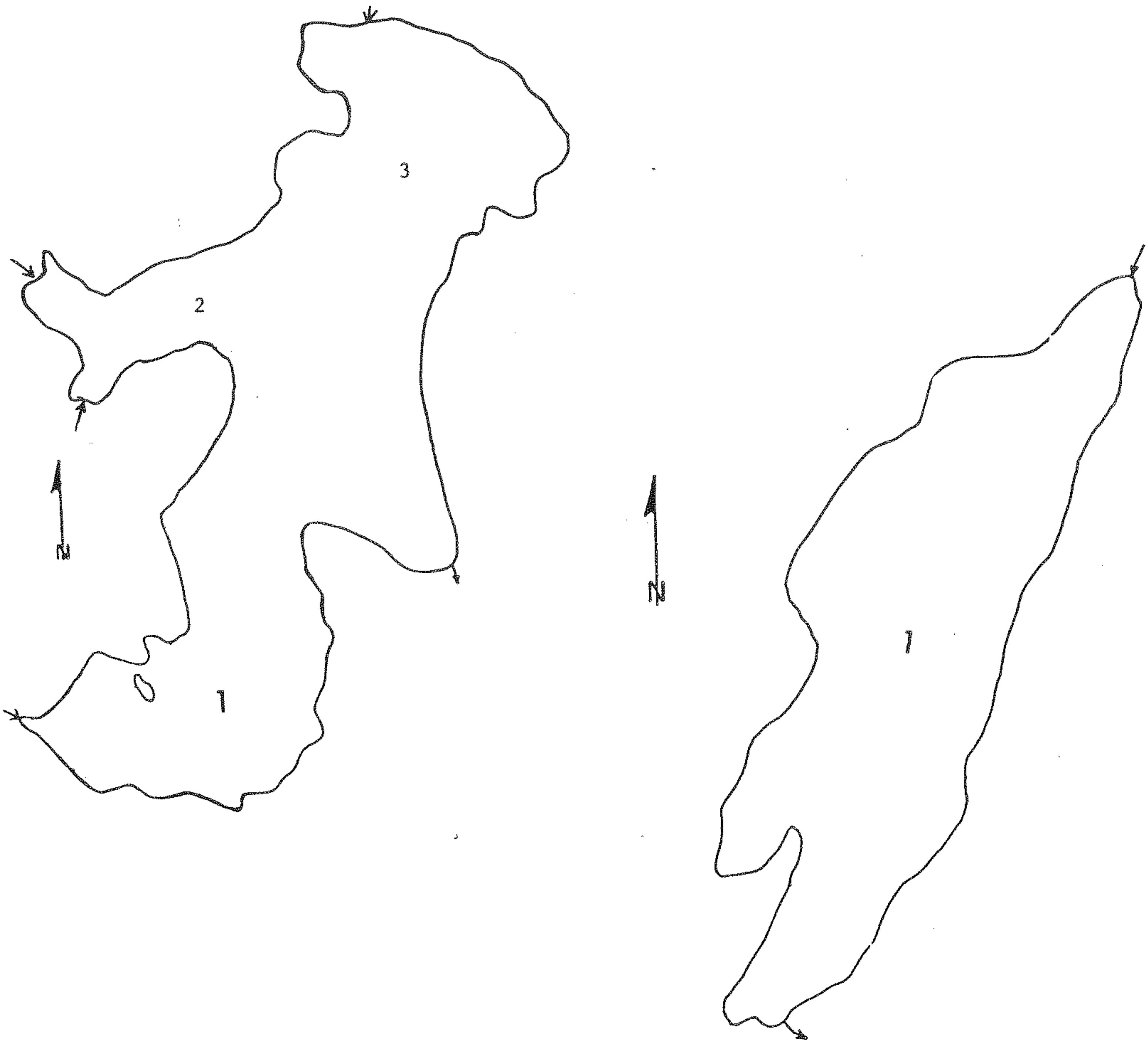


Figure 3. Shadow and Canobie Lakes, Town of Salem, New Hampshire.

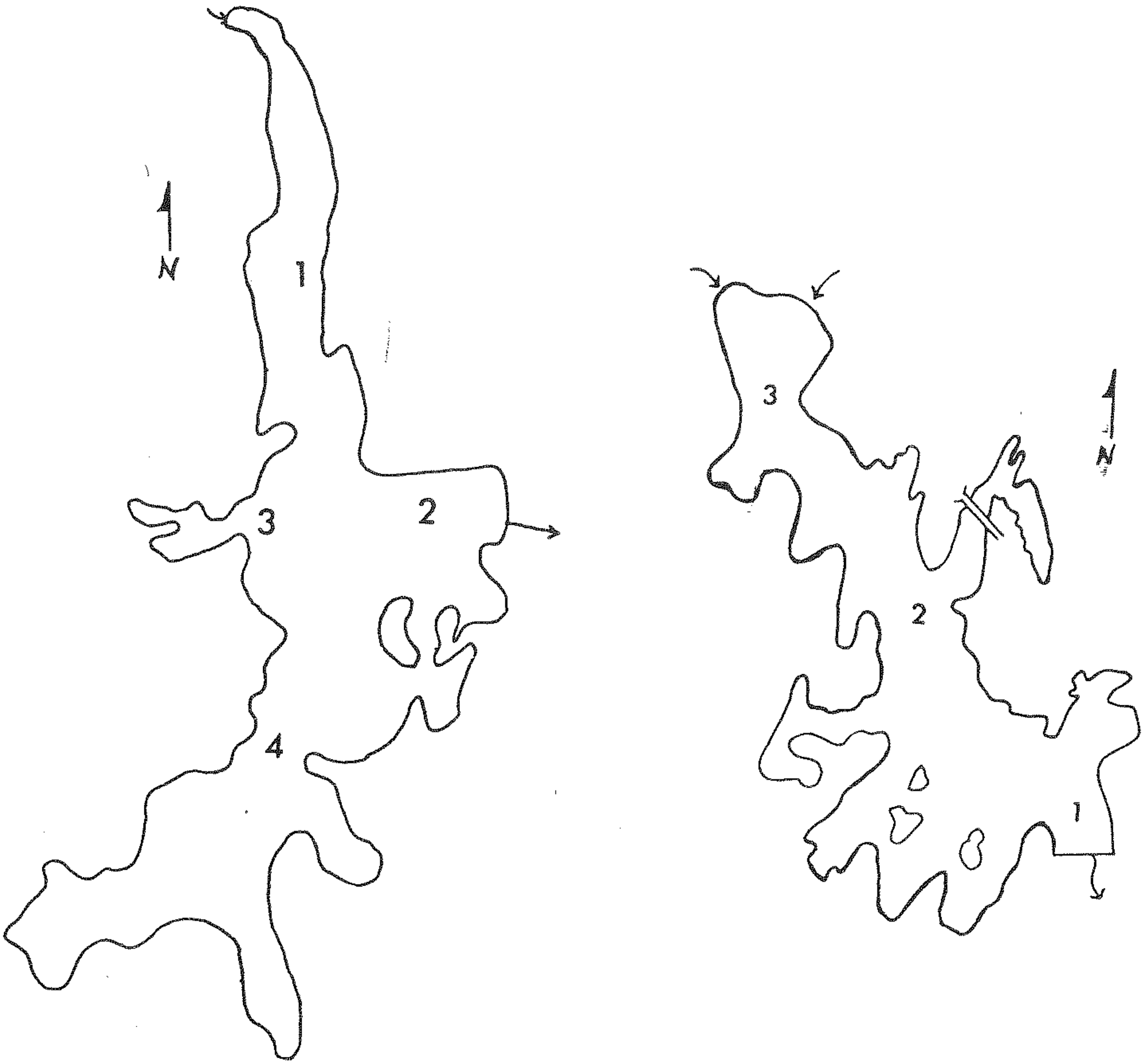


Figure 4. Millville Pond and Arlington Mill Reservoir, Town of Salem, New Hampshire.

Secchi Disk Depth (transparency)

Of the five lakes monitored by lay persons, the shallowest mean transparency was in Millville Lake (2.0 meters). In order of increasing transparency, the lakes can be ranked: Shadow Lake (3.2 meters), Captain's Pond (3.3

meters), Arlington Mill Reservoir (3.4 meters), and Canobie (6.2 meters). These means should be used only to compare differences in trophic status, as the mean for each lake is based on different sampling periods than the other lakes.

The seasonal patterns for each lake are difficult to compare, as four of the five lakes were not sampled during the entire summer. Seasonal coverage at Arlington Mill was the most complete (Fig. 5), and showed marked decreases in water clarity during early June and mid-August (Fig. 5). Sampling on Millville Lake covered July and August. Transparency was nearly constant from early July to mid-August. Seasonal coverage on Canobie, Captain's, and Shadow were incomplete, and no seasonal patterns were apparent (Fig. 5, 6).

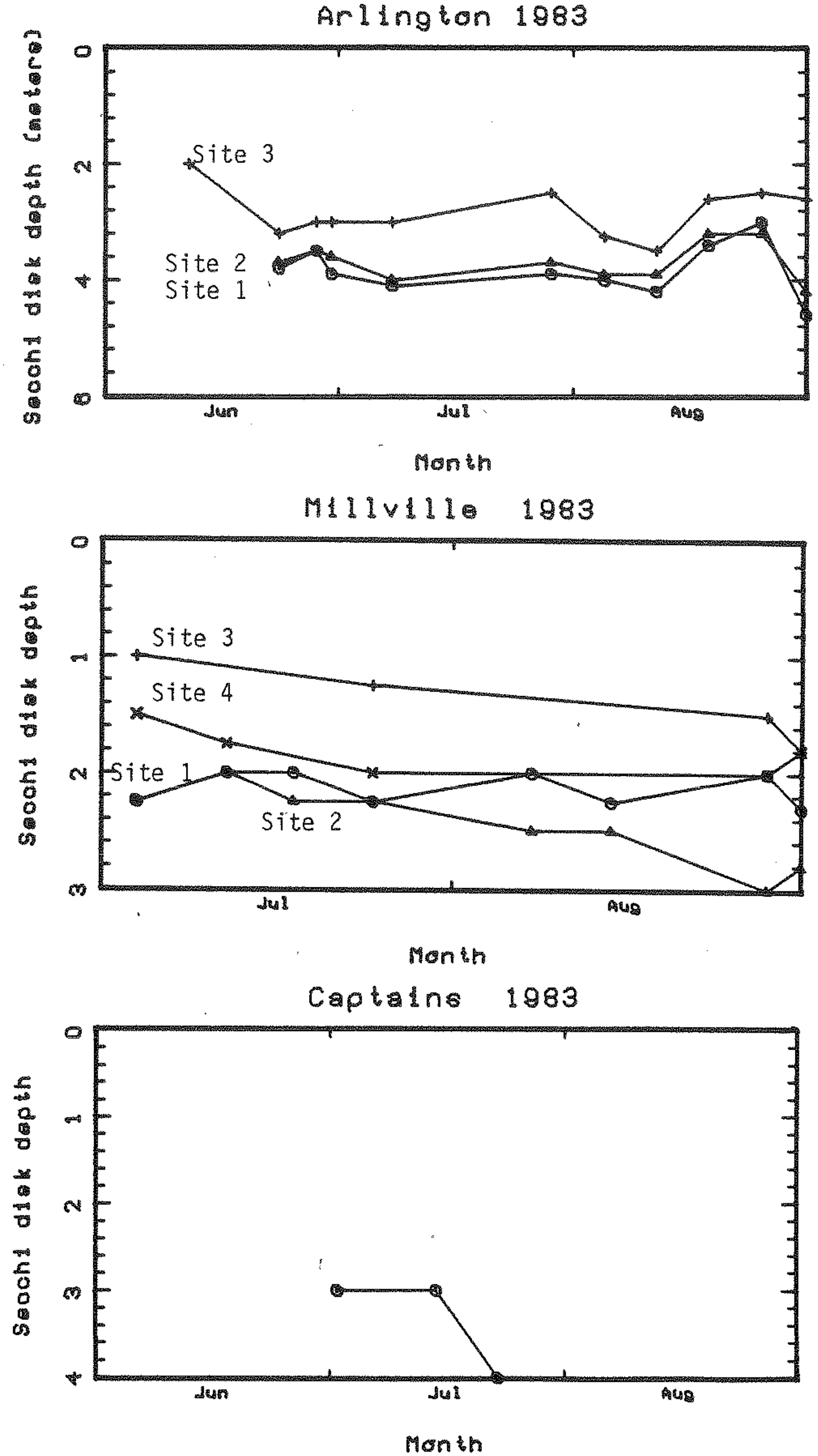
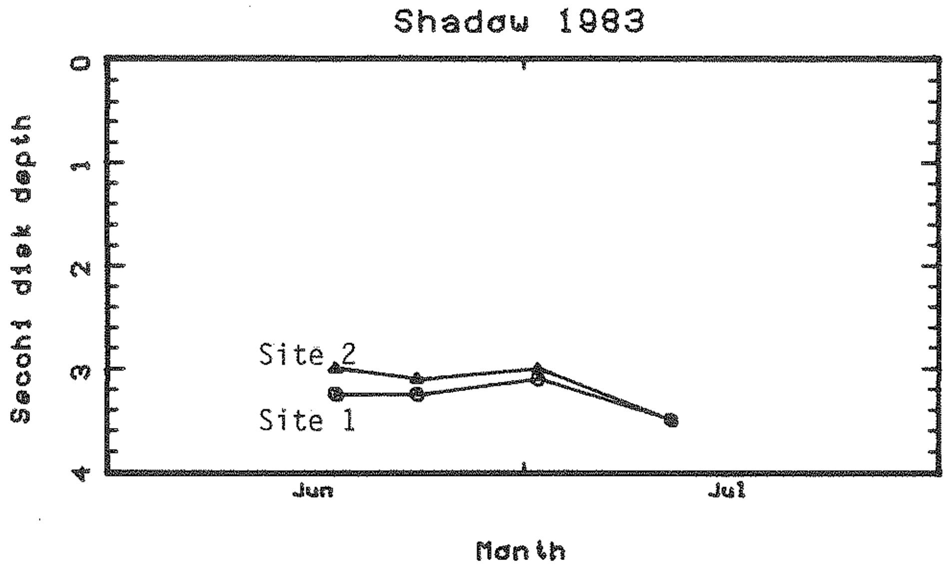


Figure 5. Seasonal variation of Secchi disk depth.



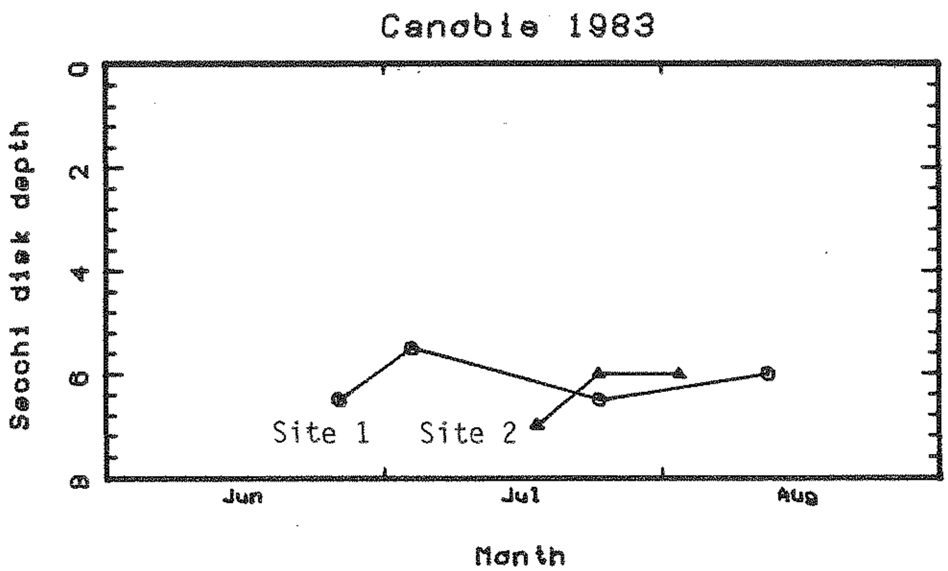


Figure 6. Seasonal variation of Secchi disk depth.

Comparisons among sites within lakes are possible for Millville, Arlington, and Shadow. In Shadow Lake, transparency at site 1 was slightly but consistently greater than at site 2 (Fig. 2). Differences in chlorophyll _a_ do not explain this difference, and it is probably due to dissolved water color, or non-chlorophyllous particulates.

In Millville Lake, water transparency was consistently lower at site 3 than the other sites, and usually lower at site 4 than at sites 1 and 2 (Fig. 2). Again, changes in chlorophyll a are not well correlated with changes in transparency. Site 3 at Arlington Mill Reservoir had a significantly lower transparency than sites 1 and 2. This is apparently not due to differences in chlorophyll a, but is quite likely due to dissolved water color, or non-chlorophyllous particles, since site 3 is located near the northern inlets.

Chlorophyll a

Of the five lakes, Canobie Lake had the lowest chlorophyll a concentration (1.1 milligrams per cubic meter). In order of increasing mean chlorophyll a concentration, the lakes can be ranked as follows: Arlington Mill (3.7 milligrams per cubic meter), Shadow (3.9 milligrams per cubic meter), Millville (4.0 milligrams per cubic meter), and Captain's (4.2 milligrams per cubic meter). Again, these means should be used only for comparisons of trophic status.

Chlorophyll a concentrations were variable between lakes, sites, and sampling dates. In Millville Lake, patterns were for the most part parallel, and showed peaks during mid-July and late August (Fig. 7). In Arlington Mill, the patterns were not quite as parallel between sites as in Millville, but peaks are apparent during late June and late August (Fig. 7). The peak in chlorophyll a concentration during late June may be due to material other than planktonic algae. During this period, large amounts of neustonic material were seen. This has apparently affected chlorophyll a samples taken by FBG members, and is a possible source of error.

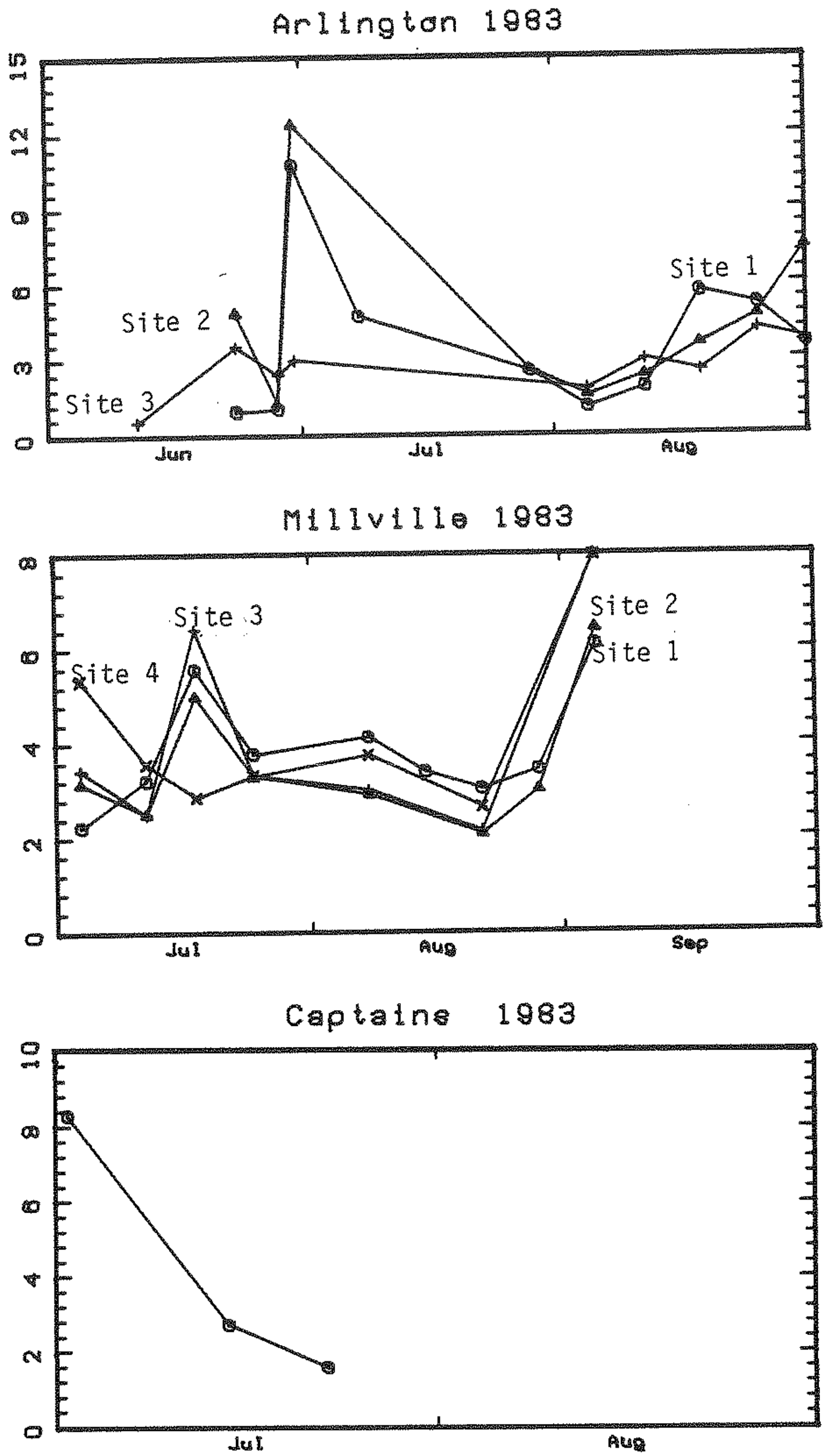


Figure 7. Seasonal variation of chlorophyll a concentration.

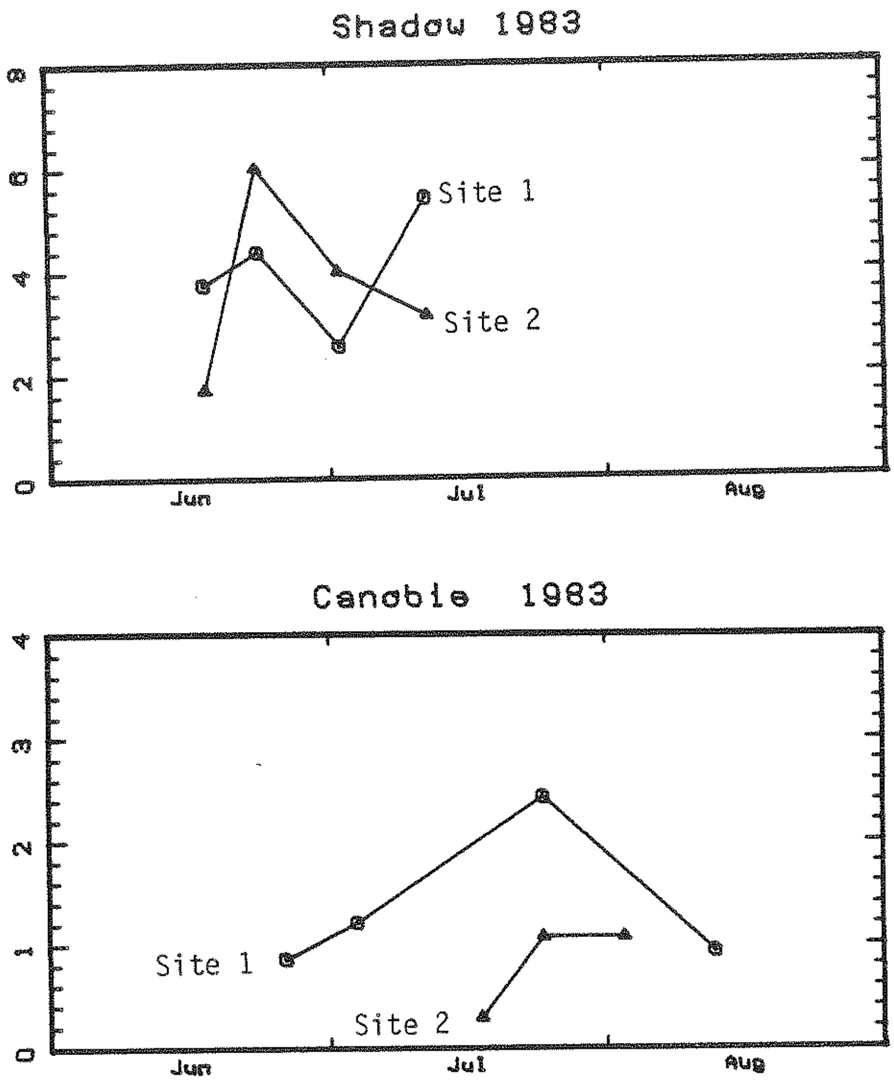


Figure 8. Seasonal variation of chlorophyll *a* concentration.

Discussion

Based on mean summer Secchi disk depth, Canobie Lake would be classed as oligotrophic; Arlington Mill, Shadow Lake, and Captain's Pond as mesotrophic; and Millville Lake as eutrophic (Fig. 4). Based on mean summer chlorophyll *a* concentration, the classification would be the same for all lakes except for Millville, which would be classed as mesotrophic (Fig. 5). A possible reason for Millville's low water clarity may be relatively large amounts of suspended non-chlorophyllous particulates. Millville's shallow mean depth (1.5 meters) may increase susceptibility to resuspension of bottom sediments and resulting decreases in water clarity.

The range of values of transparency and chlorophyll observed in the Salem lakes is also an important indication of eutrophication. The Secchi disk depth in Arlington Mill Reservoir for example ranged from oligotrophy to eutrophy. The relatively high maximum chlorophyll a concentrations, and shallow lakewater transparency may be the result of algal blooms, and indicate potential water quality degradation in the future.

Changes in lakewater transparency, or in chlorophyll a concentration from one year to the next can be used to detect changes in trophic status. Canobie Lake, Millville Lake, and Arlington Mill Reservoir have been monitored from during 1981, 1982, and 1983. Comparison between years shows no detectable trends for any of these three lakes (Fig. 11, 12). Changes in trophic status are often slow, requiring longer periods of monitoring to detect.

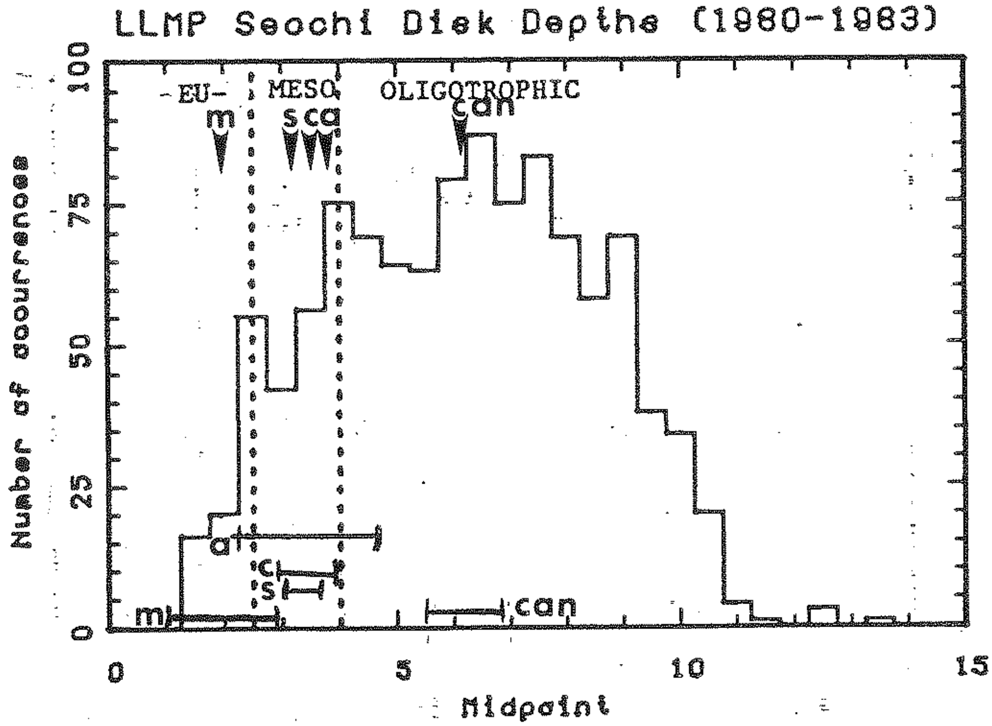


Figure 9. Frequency distribution of Secchi Disk depth. Arrow indicates mean and bar range of values from the Salem lakes.

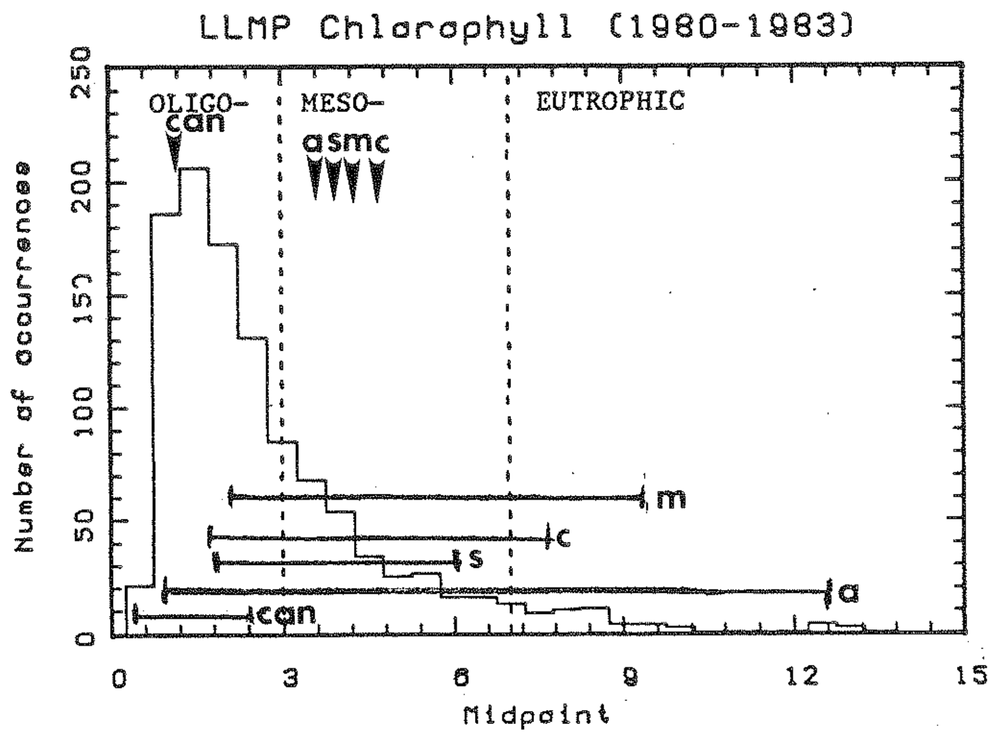
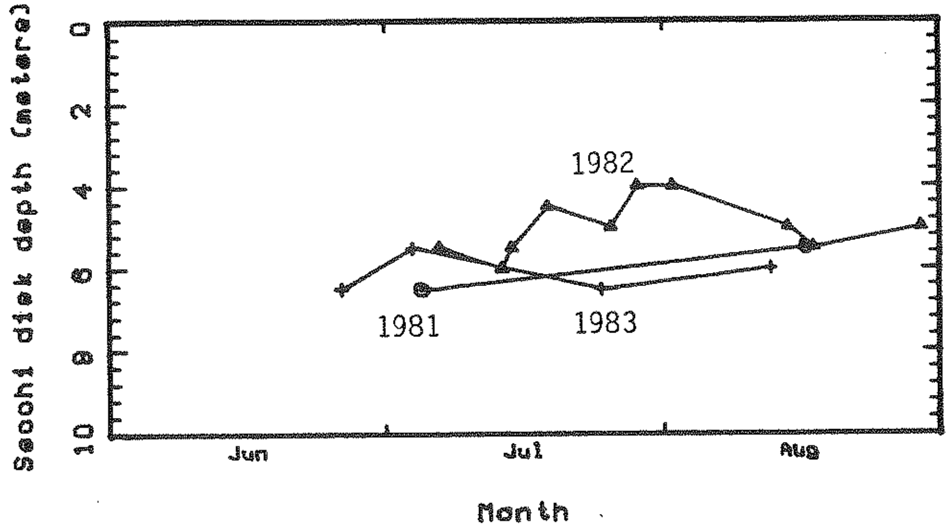
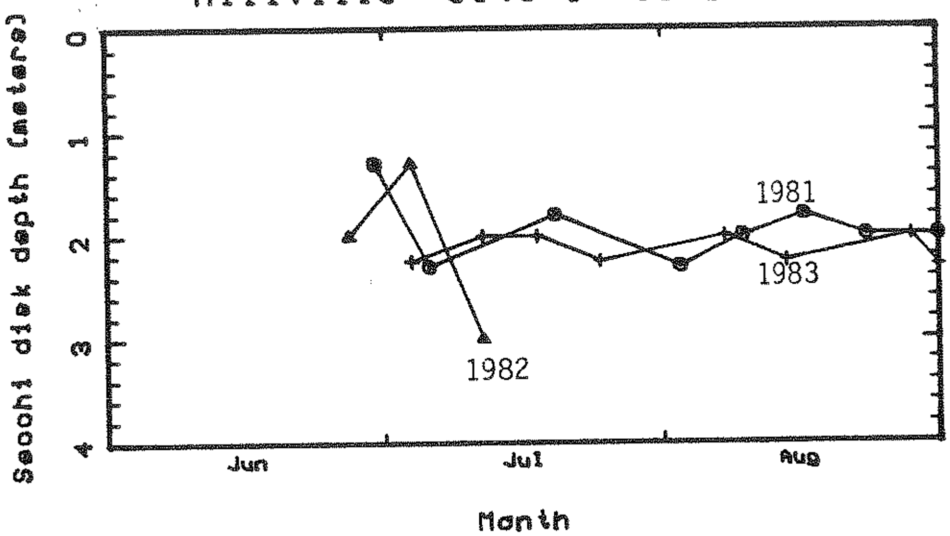


Figure 10. Frequency distribution of chlorophyll a. Arrow indicates mean and bar range of values from the Salem lakes.

Canobie Site 2 1981-1983



Millville Site 1 1981-1983



Arlington Site 1 1981-1983

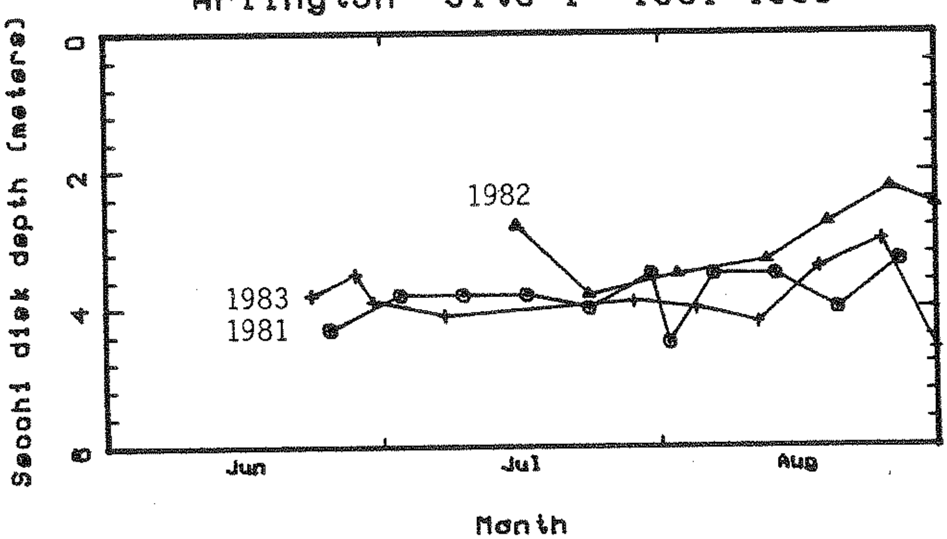


Figure 11. Comparison of Secchi disk depths 1981-1983.

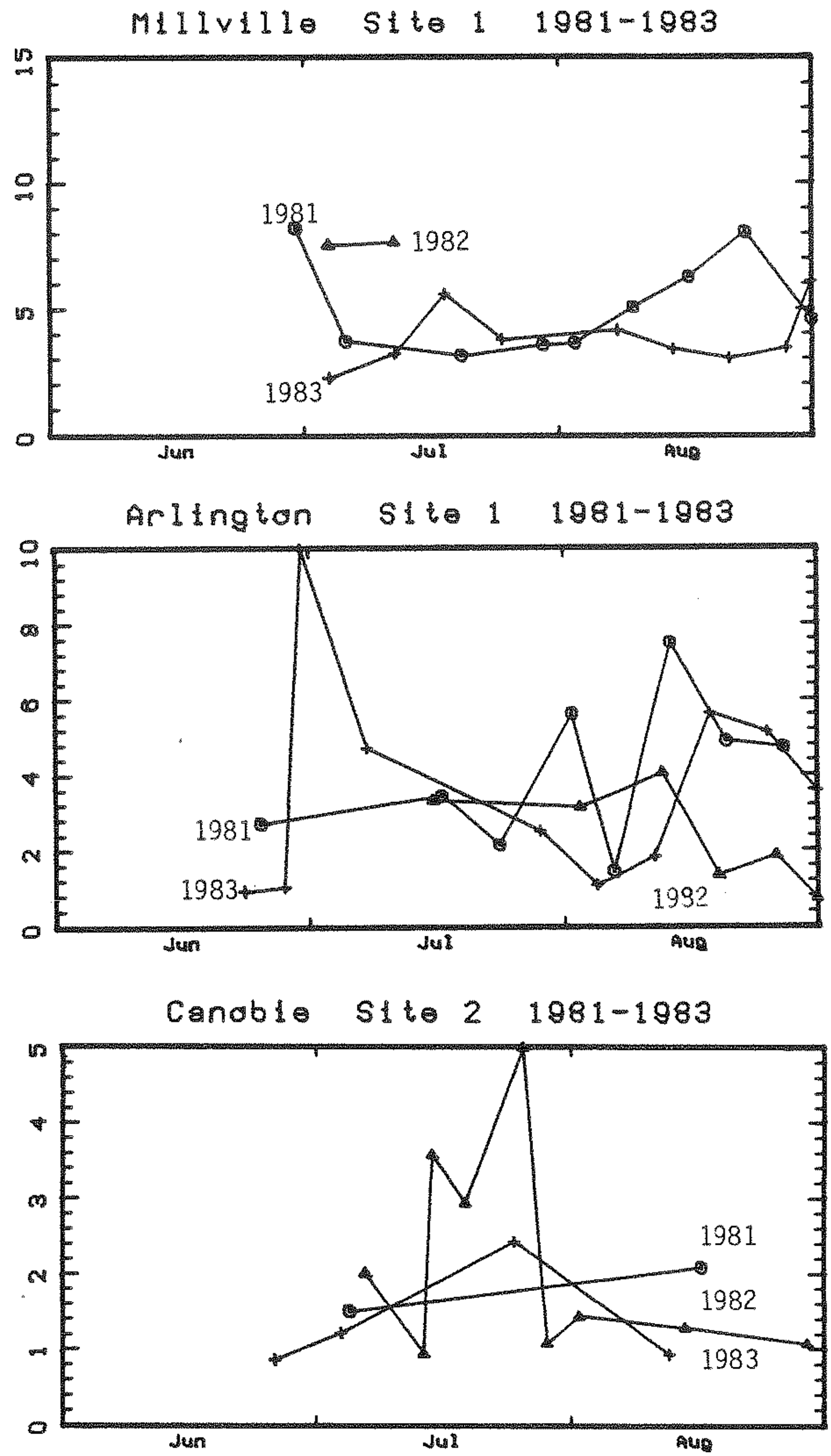


Figure 12. Comparison of chlorophyll a concentrations 1981-1983.

RESULTS AND DISCUSSION OF FRESHWATER BIOLOGY GROUP DATA

Temperature and Dissolved Oxygen

All lakes were thermally stratified on all test dates. Dissolved oxygen concentration in the thermocline and hypolimnion fell below 3 parts per million in all lakes except Millville Lake (Fig. 13). Oxygen concentrations below 3 parts per million are below the tolerance range for most fish, and concentrations below 5 parts per million may limit the growth or distribution of many fish. The combination of high epilimnetic water temperature and low meta- and hypolimnetic oxygen concentrations makes this set of lakes best suited for warm-water fish such as bass, pickerel and perch. Canobie Lake has a layer of water that may be suitable for cold-water fish such as trout, but this layer is relatively thin, and is very dependent on oxygen concentration in the thermocline and the depth of mixis. The relatively high oxygen concentration in Millville Lake is probably due to its low mean depth (1.5 meters). The degree of oxygen depletion in the hypolimnion in these lakes indicates moderate productivity.

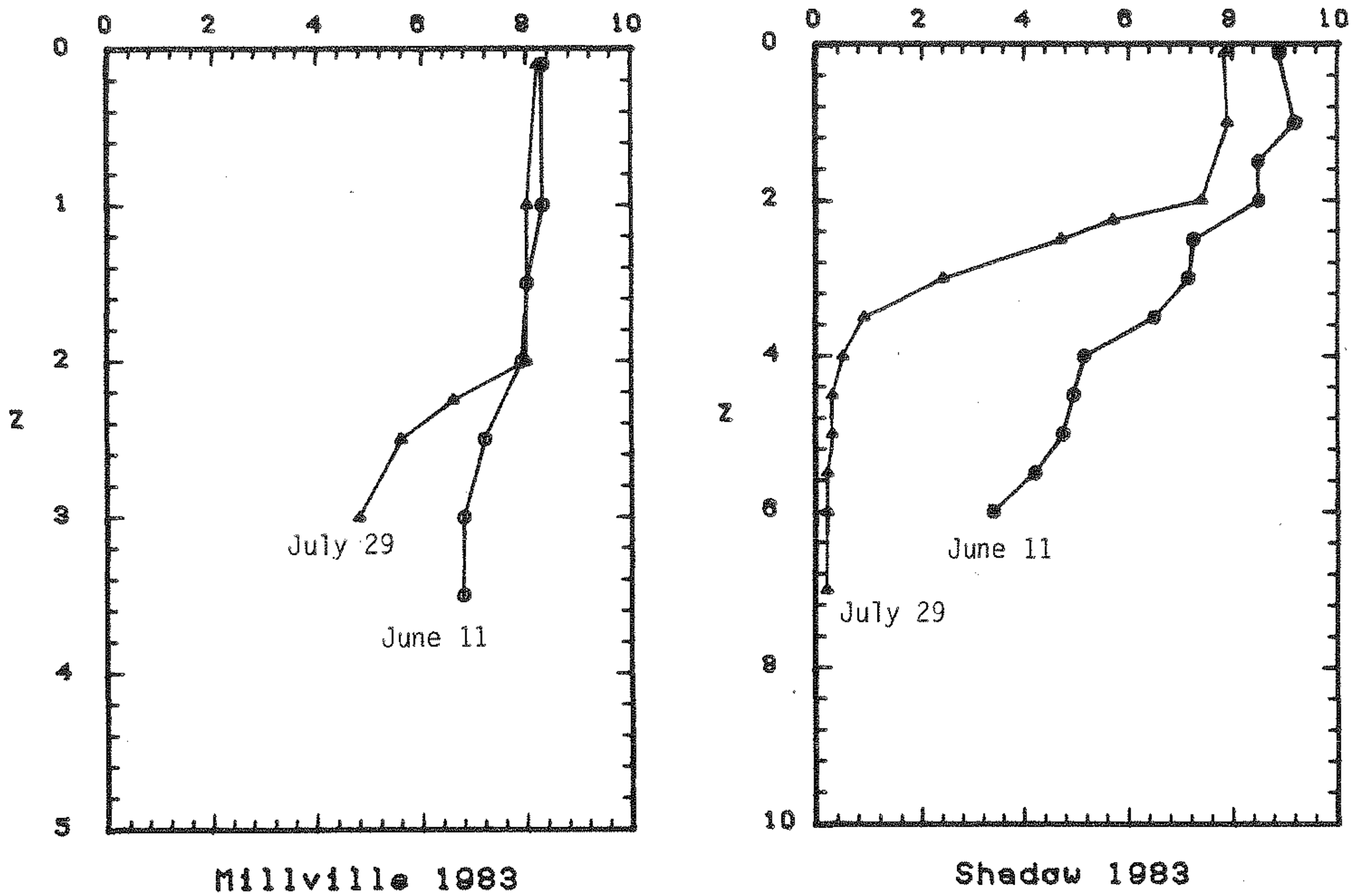


Figure 13. Oxygen profiles comparing early and late test dates.

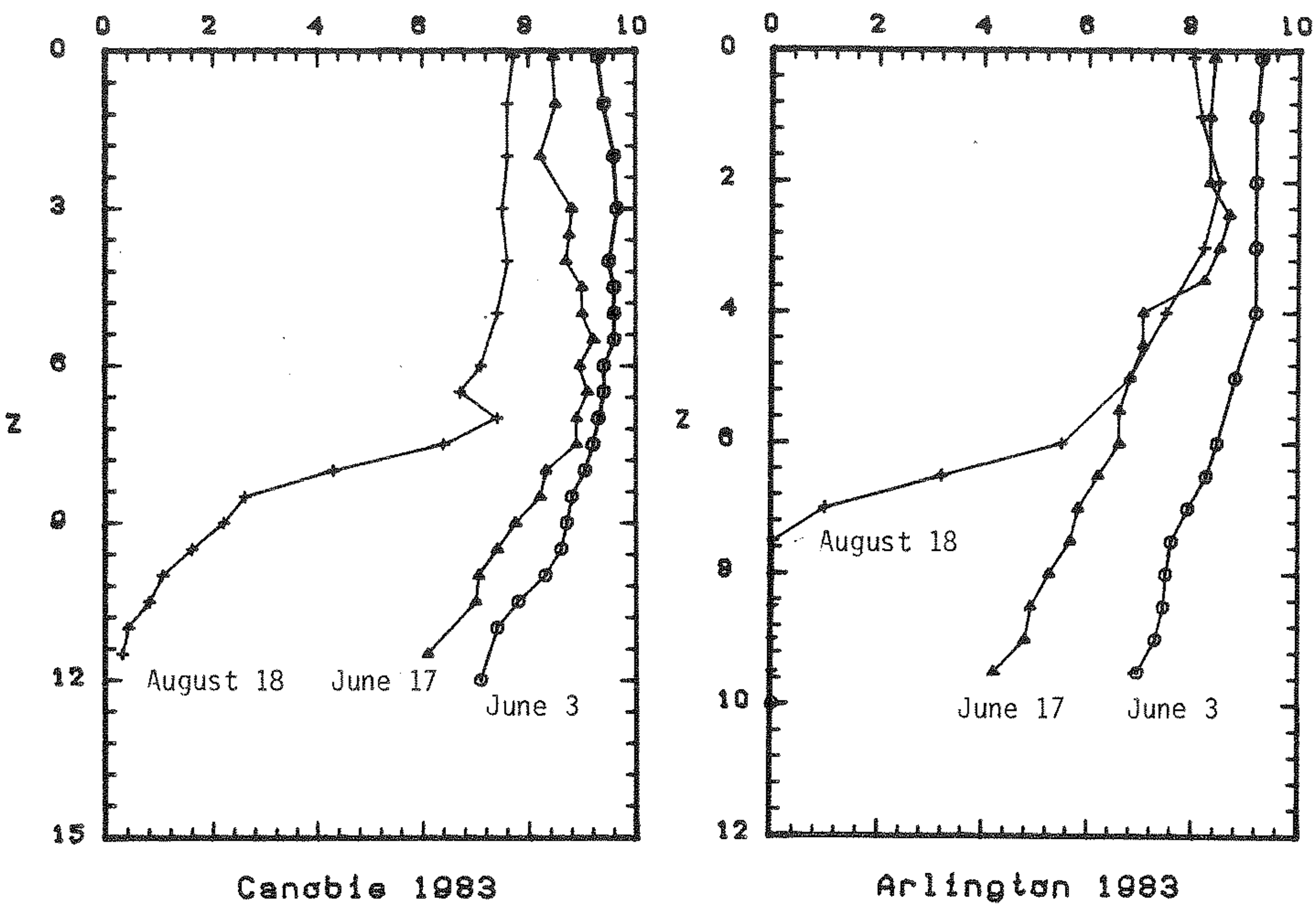


Figure 14. Oxygen profiles comparing early and late test dates.

Water Clarity and Dissolved Color

Lay monitor Secchi disk depths and FBG team Secchi disk depths were similar for overlapping time periods, indicating that lay data is comparable to data taken by trained team members.

Sunlight is quickly absorbed and scattered in lakewater by dissolved coloring material and by suspended particles. A value describing the attenuation of light in lakes is the 'extinction coefficient of diffuse downwelling light (k)'. In the Salem lakes, the value of k was in the range 0.405 - 1.64. This spans nearly the entire range of values measured from lakes in the LLMP and reflects the great differences among the Salem lakes in water clarity (Fig. 15).

Dissolved water color, primarily due to humic acids, was in the range 0.011 to 0.123. Dissolved water color was greatest in Shadow, and less in Millville, Arlington and Canobie (Fig. 16). This order is similar to that of k, except Millville and Shadow are reversed.

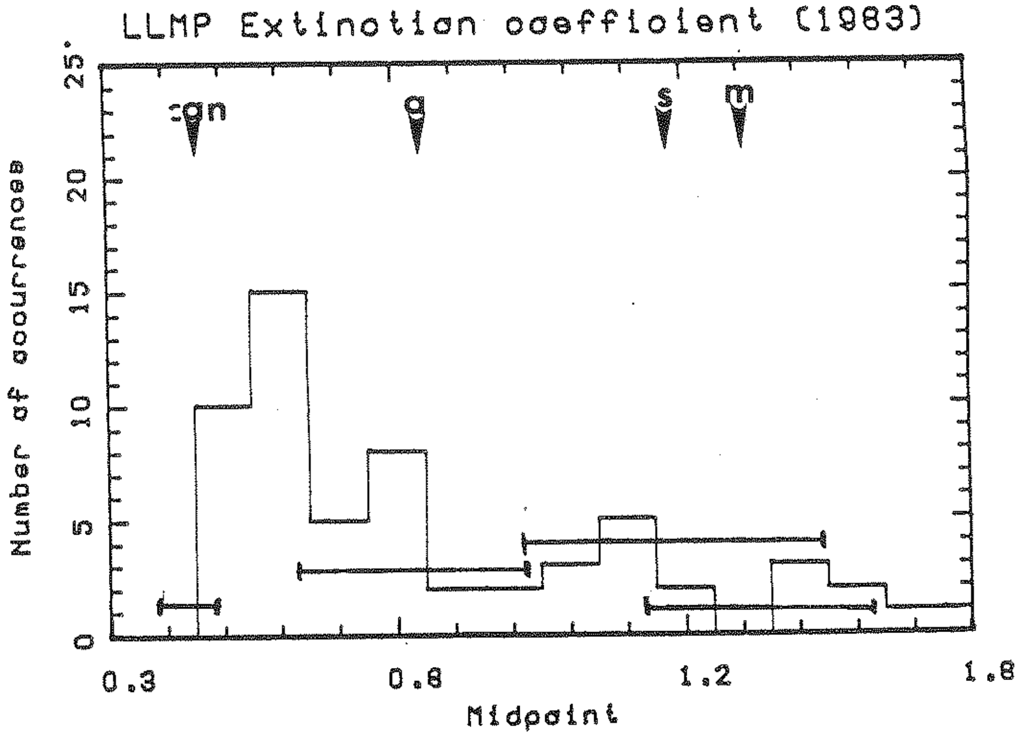


Figure 15. Frequency distribution of extinction coefficient of lakes in the LLMP. Arrow indicates mean and bar range of values from each lake.

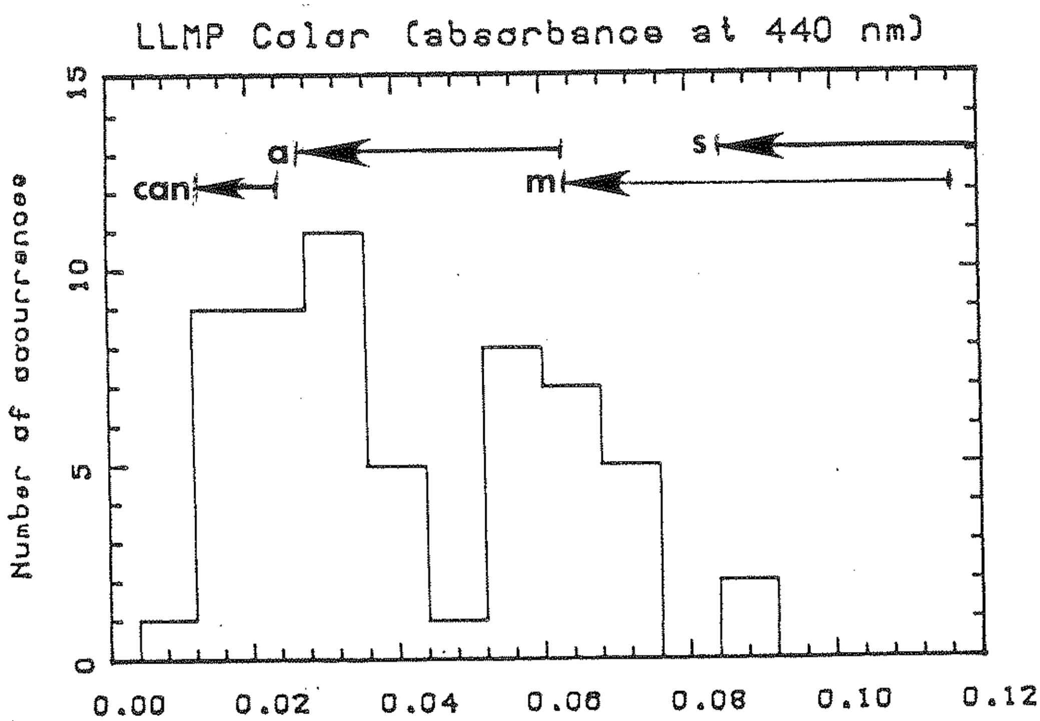


Figure 16. Frequency distribution of dissolved color of lakes in the LLMP. Arrow indicates change in dissolved color over the summer.

Chlorophyll a

Chlorophyll a concentrations measured by the FBG were similar to those measured by the lay monitors for overlapping time periods, indicating lay data is comparable to data collected by FBG members.

Total Phosphorus

Total phosphorus is usually the most important nutrient limiting algal growth in freshwater systems. Its concentration can be used as an indication of the potential for algal growth. Total phosphorus was moderate for Arlington, Millville, and Shadow Lakes. The average total phosphorus from each lake is: Arlington 15.6 micrograms per liter, Millville 19.6 micrograms per liter, and Shadow 21.2 micrograms per liter. Concentrations of total phosphorus class these lakes as mesotrophic. Canobie Lake had low concentrations (9.0 micrograms per liter) of total phosphorus, and is oligotrophic (Fig. 17).

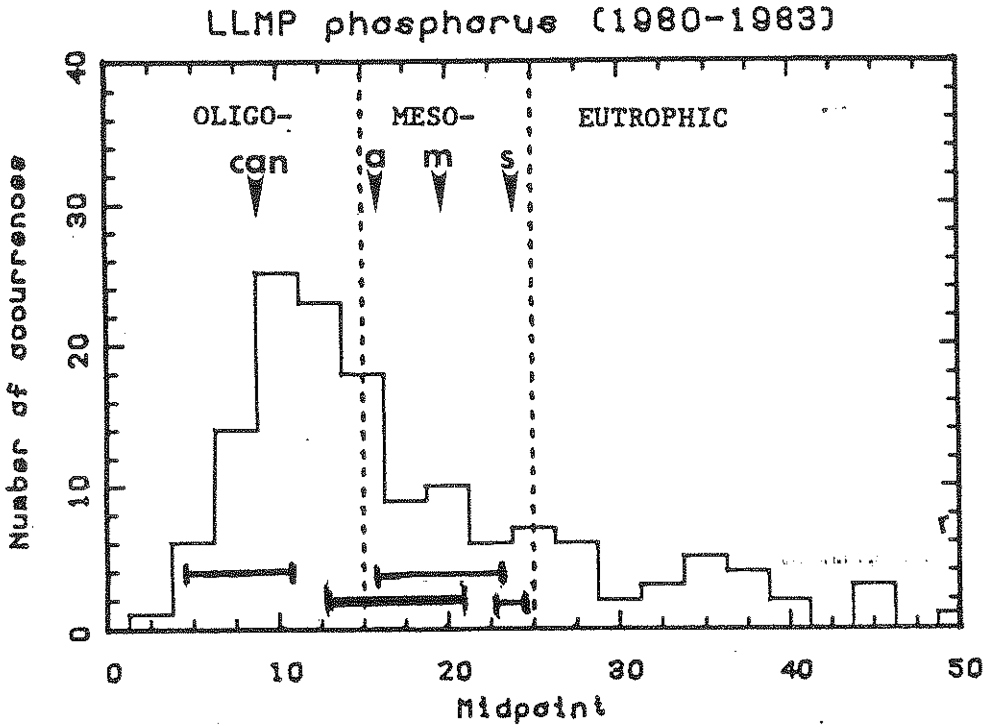


Figure 17. Distribution of phosphorus values. Arrow indicates mean and bar range of values from each lake.

Alkalinity, pH, and Free Carbon Dioxide in the range 5.4-6.4. In Canobie Lake, the pH was similar, in the range 5.9-6.4. Millville and Shadow had higher pH values: 6.6-6.6 and 6.3-6.8 respectively. Despite some low pH values in Canobie and Arlington, their alkalinities were relatively high, averaging 17.0 and 12.9 milligrams calcium carbonate per liter. Millville and Shadow also had relatively high alkalinities (17.3 and 14.1 milligrams calcium carbonate per liter) for New Hampshire waters. Although these alkalinities are high for New Hampshire, compared to lakes around the United States, these are low values.

Free carbon dioxide accumulated in the thermoclines and hypolimnia of the Salem lakes, lowering the pH of these layers of lakewater. The amount of free carbon dioxide in the deep waters indicates moderate productivity in the Salem lakes.

Specific Conductivity and Chloride Ion Concentration

Based on specific conductivity, the Salem lake have some of the highest salt concentrations among the lakes in the LLMP. Canobie had the highest among the Salem lakes, 161.2 micromhos per cm. Next was Millville at 138.6 micromhos per cm, then Shadow at 134.5 micromhos per cm, and finally Arlington at 94.1 micromhos per cm. These relatively high conductivities are associated with high chloride ion concentrations. Again Canobie was the highest, with 29.2 parts per million. Shadow had 28.7, Millville 27.4, and Arlington 14.6 parts per million. High conductivities and chloride ion concentrations are associated with inputs of road salt and/or inputs of sewage. In Arlington, Millville and Shadow, it could be either of these inputs, or a combination of the two. In Canobie, the probable source is road salting, as inputs of sewage would probably have resulted in higher total phosphorus concentrations.

Phytoplankton

Lowest densities of phytoplankton occurred in Arlington Mill Reservoir. Densities ranged from 813-935 cells per milliliter. Seasonally important groups included: Cryptomonads (dominant over most of the summer; *Chroomonas*, *Cryptomonas*), Chlorophytes (*Elakatothrix*, *Ankistrodesmus*, and small flagellated forms), and Diatoms (*Cyclotella*, *Rhizosolenia*). The low density of groups such as Blue-green bacteria and Euglenoids is an indication of oligotrophic-mesotrophic conditions. Canobie had the next lowest phytoplankton density, with 946-1033 cells per milliliter. Chlorophytes (small flagellated forms), and Cryptomonads (primarily *Chroomonas*) were dominant. Early in June, *Dinobryon* (a Chrysophyte) was also of numerical importance. Again the lack of Blue-greens and Euglenoids is a sign of oligotrophic-mesotrophic conditions. Millville and Shadow were similar in phytoplankton densities (1001-1532 cells per milliliter and 1524 cells per milliliter), but were very different in species composition. Millville was dominated by Cryptomonads (*Chroomonas*) and Chrysophytes (*Dinobryon*, *Kephyrion*) early in the season, and was dominated by Chrysophytes (*Chrysosphaerella*, *Dinobryon*) and Chlorophytes (small flagellated forms, small unicells, and *Ankistrodesmus*) later in the season. Shadow Lake, however, was dominated by Cryptomonads (*Chroomonas*, *Cryptomonas*) and Chrysophytes (*Chrysosphaerella*) during the latter part of the season. Both these lakes showed low numbers of

Blue-green bacteria (*Merismopedia*, *Chroococcus*, *Anabaena*), indicating eutrophic tendencies.

Zooplankton

The lowest density of zooplankton occurred in Arlington Mill Reservoir. Densities ranged from 5 to 11 animals per liter. The dominant crustacean zooplanktor over the season was calanoid copepods, but *Daphnia*, *Bosmina*, and Chydorids were also seasonally abundant. Canobie Lake also had relatively low densities of crustacean zooplankton, in the range 11 - 13 animals per liter. Dominant groups in Canobie were calanoid copepods, and *Daphnia*. Both of these lakes showed an increase in the dominance of calanoid copepods during August. This may be related to an increase in fish predation, and preferential feeding on *Daphnia* over calanoids.

Shadow Lake had moderately high zooplankton densities (10-20 animals per liter), and had a rather diverse community. Dominant groups included: calanoid copepods, *Daphnia parvula*, *Daphnia catawba*, *Daphnia ambigua*, *Bosmina*, *Holopedium*, and *Ceriodaphnia*. Millville Lake had the highest crustacean zooplankton density of the five Salem lakes, and one of the greatest densities of any of the lakes involved with the LLMP. Densities were in the range 40-91 animals per liter. Throughout the season the dominant species was *Daphnia parvula*. Also numerically important, but much less so were *Holopedium, and Bosmina*. Populations of cyclopoid copepods were relatively dense (19 animals per liter) during the peak of the *Daphnia* population. The density of zooplankton in Millville suggest a eutrophic system, and indicate higher production than biomass (chlorophyll *a*) or transparency alone suggest.

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APPENDIX A

LLMP 1983 -- Lay Monitor Data: Salem Jan-09-84 14:37.17

Date	Lake	Site	SDD	Chl
Jun-23-83	Arlington	1	3.80	.93
Jun-28-83	Arlington	1	3.50	1.03
Jun-30-83	Arlington	1	3.90	10.77
Jul-07-83	Arlington	1	4.10	4.71
Jul-28-83	Arlington	1	3.90	2.50
Aug-04-83	Arlington	1	4.00	1.07
Aug-11-83	Arlington	1	4.20	1.83
Aug-18-83	Arlington	1	3.40	5.63
Aug-25-83	Arlington	1	3.00	5.14
Sep-01-83	Arlington	1	4.60	3.57
Jun-23-83	Arlington	2	3.70	4.86
Jun-28-83	Arlington	2	3.50	1.22
Jun-30-83	Arlington	2	3.60	12.37
Jul-07-83	Arlington	2	4.00	---
Jul-28-83	Arlington	2	3.70	2.55
Aug-04-83	Arlington	2	3.90	1.53

Aug-11-83	Arlington	2	3.90	2.32
Aug-18-83	Arlington	2	3.20	3.57
Aug-25-83	Arlington	2	3.20	4.71
Sep-01-83	Arlington	2	4.20	7.43
Jun-11-83	Arlington	3	2.00	.51
Jun-23-83	Arlington	3	3.20	3.50
Jun-28-83	Arlington	3	3.00	2.38
Jun-30-83	Arlington	3	3.00	2.96
Jul-07-83	Arlington	3	3.00	---
Jul-28-83	Arlington	3	2.50	---
Aug-04-83	Arlington	3	3.25	1.78
Aug-11-83	Arlington	3	3.50	2.94
Aug-18-83	Arlington	3	2.60	2.50
Aug-25-83	Arlington	3	2.50	4.14
Sep-01-83	Arlington	3	2.60	3.71
Jun-26-83	Canobie	2	6.50	.86
Jul-03-83	Canobie	2	5.50	1.21
Jul-24-83	Canobie	2	6.50	2.43
Aug-12-83	Canobie	2	6.00	.93
Jul-17-83	Canobie	3	7.00	.29
Jul-24-83	Canobie	3	6.00	1.07
Aug-02-83	Canobie	3	6.00	1.07

Jul-01-83	Captains	1	3.00	8.28
Jul-14-83	Captains	1	3.00	2.71
Jul-22-83	Captains	1	4.00	1.57
Jul-03-83	Millville	1 Beach	2.25	2.23
Jul-11-83	Millville	1 Beach	2.00	3.21
Jul-17-83	Millville	1 Beach	2.00	5.58
Jul-24-83	Millville	1 Beach	2.25	3.78
Aug-07-83	Millville	1 Beach	2.00	4.13
Aug-14-83	Millville	1 Beach	2.25	3.39
Aug-21-83	Millville	1 Beach	---	3.02
Aug-28-83	Millville	1 Beach	2.00	3.44
Sep-04-83	Millville	1 Beach	2.30	6.10
Jul-03-83	Millville	2 Dam	2.25	3.14
Jul-11-83	Millville	2 Dam	2.00	2.50
Jul-17-83	Millville	2 Dam	2.25	5.00
Jul-24-83	Millville	2 Dam	2.25	3.29
Aug-07-83	Millville	2 Dam	2.50	2.90
Aug-14-83	Millville	2 Dam	2.50	---
Aug-21-83	Millville	2 Dam	---	2.06
Aug-28-83	Millville	2 Dam	3.00	3.00
Sep-04-83	Millville	2 Dam	2.80	6.43
Jul-03-83	Millville	3 Woodmea	1.00	3.43

Jul-11-83	Millville	3 Woodmea	---	2.50
Jul-17-83	Millville	3 Woodmea	---	6.43
Jul-24-83	Millville	3 Woodmea	1.25	3.31
Aug-07-83	Millville	3 Woodmea	---	3.00
Aug-14-83	Millville	3 Woodmea	---	---
Aug-21-83	Millville	3 Woodmea	---	2.12
Aug-28-83	Millville	3 Woodmea	1.50	---
Sep-04-83	Millville	3 Woodmea	1.80	9.44
Jul-03-83	Millville	4 Grove C	1.50	5.36
Jul-11-83	Millville	4 Grove C	1.75	3.57
Jul-17-83	Millville	4 Grove C	---	2.86
Jul-24-83	Millville	4 Grove C	2.00	3.31
Aug-07-83	Millville	4 Grove C	---	3.75
Aug-14-83	Millville	4 Grove C	---	---
Aug-21-83	Millville	4 Grove C	---	2.64
Aug-28-83	Millville	4 Grove C	2.00	---
Sep-04-83	Millville	4 Grove C	1.80	7.98
Jun-17-83	Shadow	1	3.25	3.75
Jun-23-83	Shadow	1	3.25	4.39
Jul-01-83	Shadow	1	3.10	2.55
Jul-11-83	Shadow	1	3.50	5.43
Jun-17-83	Shadow	2	3.00	1.71

Jun-23-83	Shadow	2	3.10	6.02
Jul-01-83	Shadow	2	3.00	4.00
Jul-11-83	Shadow	2	3.50	3.14

>>> END OF LIST <<<

APPENDIX B

CLARIFICATION OF SOME TERMS AND CONCEPTS

Thermal Stratification

Thermal stratification as a seasonal phenomenon is of prime importance in the lives of aquatic organisms. The formation of thermal layers affects many of the chemical and physical factors of their environment.

New Hampshire lakes are generally <u>dimictic</u>, with mixing of the water column occurring in the spring and fall. During periods of mixing, sometimes called <u>overturn</u>, the entire water column tends to circulate (<u>holomixis</u>). That is, the bottom-most waters are refreshed with water recently in contact with the atmosphere. The surface waters are enriched with water recently in contact with the bottom sediments. Some lakes, especially those with a high salt content toward the bottom of the basin, may be <u>meromictic</u> and fail to mix (<u>overturn</u>) to the bottom.

During the spring, the entire water column circulates freely, resuspending and redissolving material from the bottom sediments. As the sun's intensity increases, the surface waters are heated so that they become buoyant and tend to float, creating a mixing-barrier with cooler water beneath. Eventually three layers are formed, called the upper-lake (epilimnion), middle-lake (metalimnion), and lower-lake (hypolimnion) (Fig. B-1). Characteristically, the epilimnion and hypolimnion are uniform in temperature, even though the upper lake is warm and the lower lake is usually very cold. In contrast, the temperature gradually or suddenly becomes cooler in the metalimnion (sometimes called the thermocline, or temperature gradient). The gradation in temperature corresponds to a gradient in other important characteristics of water, such as viscosity and specific gravity, that explain the presence of a mixing barrier between the epilimnion and the hypolimnion.

Depth of the metalimnion through the summer is variable, and is regulated to a large extent by the length of the wind-fetch on the lake (the length of lake aligned with the predominant axis of wind-storms). In the autumn, the sun's intensity decreases, the water in the epilimnion cools, and the mixing barrier weakens. Eventually the metalimnion disintegrates and the fall overturn occurs.

Ice and snow insulate the lakewater during winter, and the liquid lakewater cools to nearly freezing just under the ice layer, while it remains relatively warm further down in the water column (about 10 degrees Fahrenheit, or 4 degrees Celsius). Sometimes the overburden of snow after a heavy snowstorm in January or February may cause melt-holes to form in the ice, and the snow may turn to slush even while the air temperature is at its seasonal coldest (as low as 25 or 30 degrees below zero Fahrenheit)! This has caused some hysteria about 'radioactive things dropping from outer space' or 'radioactive substances dropping from jet planes' -- even though it is only the weight of snow! Some reverse stratification may occur, with a layer of colder water overlying the relatively warmer water below.

Two aspects of the seasonal thermal stratification cycle about which we are most concerned are vertical mixing (<u>overturn</u>) and the formation of stratified temperature layers during the summer.

Periods of <u>overturn</u> are very important because of their effect of enriching the lakewater with material from the sediments. In <u>eutrophic</u> lakes, blooms of algae generally follow these periods in response to high concentrations of chemicals such as phosphorus, nitrogen, silica, and other essential <u>nutrients</u> -- those required for the growth of <u>microscopic algae</u>.

Effects of stratification will vary depending upon the depth of the lake or cove. In shallow areas, the epilimnion may extend to the bottom. If this is the case, the lakewater will constantly pick up material from the bottom usually resulting in a decrease in water transparency and an increase in algal growth.

One of the major consequences of a stratified lake system is reduced transportation of material between the bottom and surface. The effects of having a "barrier" within the water column are many but the most important include transport of nutrients from the epilimnion to the hypolimnion by sedimentation (enriching the hypolimnion at the expense of the epilimnion), and oxygen depletion in the hypolimnion.

Loss of nutrients from the epilimnion is due primarily to the sedimentation of plankton organisms such as algae and bacteria. The depletion of nutrients from the epilimnion is important for restricting the growth of algae during the summer, because the primary productivity of most lakes occurs only in the epilimnion. As a result of fall overturn the surface waters may become mixed with nutrient-rich bottom waters, and fall pulses of phytoplankton (freely-drifting microscopic algae) may develop.

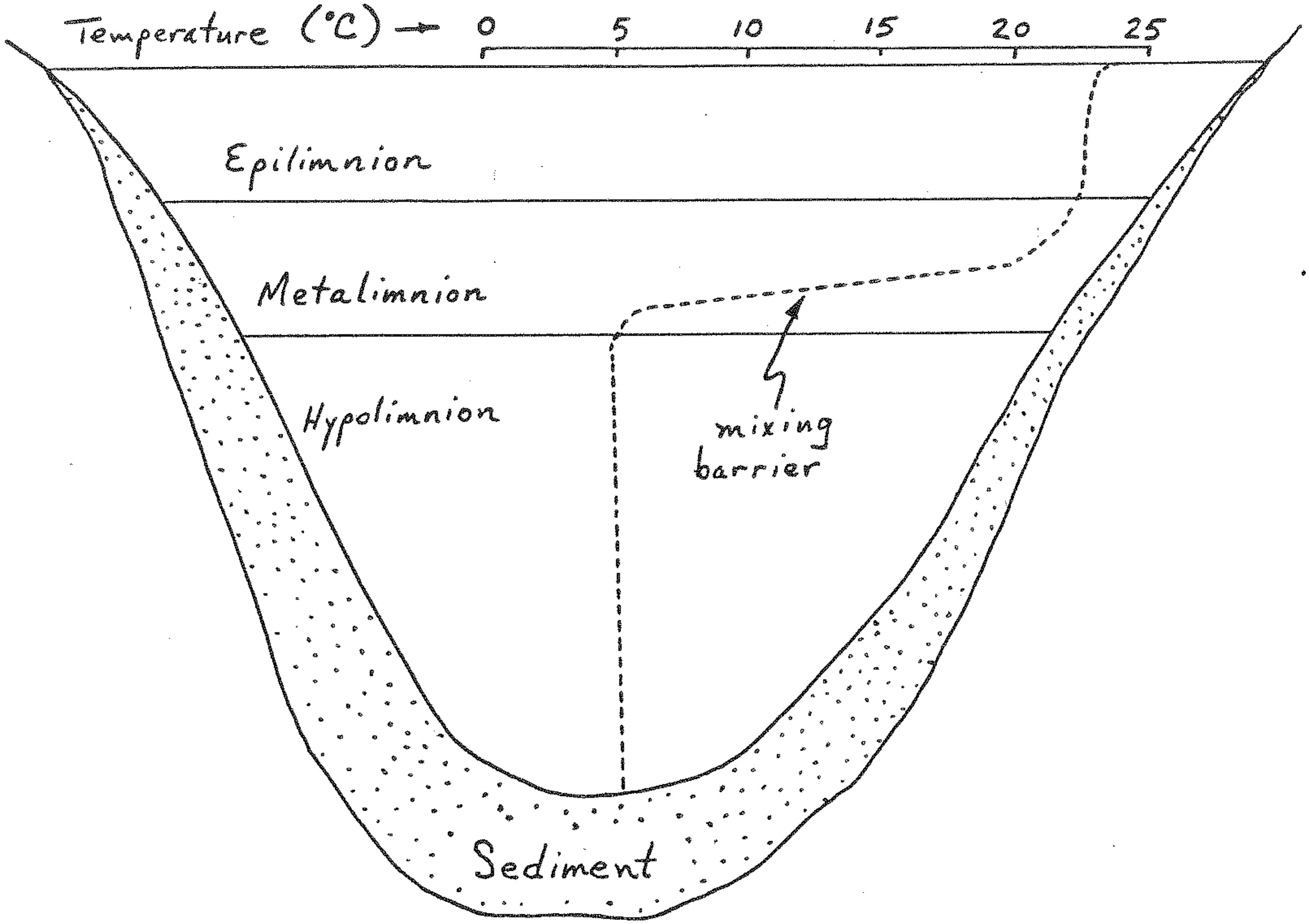

Figure B-1. Typical summer thermal stratification of a temperate lake. The 'metalimnion' provides a mixing barrier between the 'epilimnion' and the 'hypolimnion'. The dashed line represents the thermal profile, with cold water in the hypolimnion.

Oxygen Depletion

Oxygen depletion in the hypolimnion occurs for two reasons -- respiration by plants, bacteria and animals, and absence of mixing of the water column (combined with respiration). The resultant loss of oxygen plays an important role in regulating the depth regions within which aerobic (requiring oxygen) and anaerobic (oxygen-avoiding) organisms may thrive. The aerobic organisms include some bacteria, most algae, and all animals, and although they may have special adaptations to allow a tolerance to very low levels of dissolved oxygen, even for prolonged periods of time, they must occasionally obtain a supply of oxygen. The algae are the principal source of re-oxygenation by photosynthesis in the metalimnion, and the balance between oxygen production (by photosynthesis) and consumption (by respiration) is critical in determining the oxygen depletion in lakewater. The problem is minimal in surface waters, as the atmosphere overhead is a good source of oxygen.

Fisherman are acutely aware of the oxygen requirement of fish, and know that they can expect no laketrout fishing where oxygen has been depleted in the cool bottom waters of a lake. In fact, the laketrout, as well as related species of fish, are entirely eliminated from such lakes. Even though the surface waters are well oxygenated, the temperature is too high to support the salmonid-type fish.

Most people are unaware that important groups of micro-organisms thrive in the anoxic (lacking oxygen, similar to anaerobic) bottom waters of lakes. For the most part, these are the important groups of bacteria that regulate cycles of nutrients at or near the bottom of such lakes. The bacteria are involved in crucial processes that may determine the chemical quality of the lake -- including modification of all nutrients essential to growth of the microscopic algae -- such as carbon, phosphorus nitrogen, and sulphur, by putrefaction or break-down of dead organisms, and by fermentation. The anaerobic bacteria are also involved in processes such as nitrogen fixation that converts unavailable nitrogen to very-available ammonia, and in the formation of a large host of dissolved organic substances such as vitamins that promote the growth of microscopic algae. In general, the anaerobic bacteria can be viewed as the principal agents involved in promoting recycling of essential nutrients that otherwise would have been lost and locked up in the lake sediments.

Water transparency

Water transparency, as indicated by secchi disk depth, is influenced by many factors. Dissolved substances such as humic acids (tea-colored coloring matter from plant decay) will frequently lend a yellow or brown color to the water, thus decreasing its transparency. The humic acids are especially prevalent in waters running through bogs or coniferous forests.

Another factor affecting water transparency is the number of particles suspended in the water column. These particles are of two types: sediments and living organisms. Sediments are especially prevalent in areas where mixing occurs all the way to the bottom, as during overturn of holomictic lakes. Human activity such as boating or swimming can also resuspend sediments. Among living organisms, phytoplankton has the greatest effect on water transparency, due to its pigmentation and abundance. Chlorophyll a, the pigment common to all photosynthetic phytoplankton, is used as one measure of phytoplankton density.

Water transparency (measured as the Secchi Disk Depth), chlorophyll a and thermal stratification, along with other important physical, chemical and biological obsevations of study lakes, are the core of the lay monitoring program. Long- or short-term trends in these data can be used as indicators of changing trophic status of lakes.

Lake Trophic Status

Every classification scheme suffers from over-simplification! The very act of classifying requires the definition of classes within which study objects may be placed or pigeon-holed. Often the classes are defined by some arbitrary means, and the boundaries are subject to change depending upon the definition that is used. The fundamental problem with the process of classification is that once boundaries are set and classes are defined, we tend to think of the classes as somehow isolated from each other. Instead they may blend into each other at the boundaries. As you consider the classification scheme, please think of a continual gradient of individual lake types, through which any lake may pass. The passage may require a long period of time, given changes in the landscape or climate by natural causes, or a relatively short time given human-induced changes in use of the lake or its shoreline and watershed. One may hope that the following five categories of trophic status will help to simplify what we know about lakes, yet leave us with a sense of the probable evolution of lakes between classes of trophic status.

Three major categories of trophic status include oligotrophy, mesotrophy, eutrophy. Oligotrophic lakes characteristically have high transparency and low concentrations of chlorophyll a and phosphorus. Therefore, a large fraction of the visible portion of sunlight radiation, including from blue through red light, can penetrate to great depths in the lakes. Mesotrophic lakes are intermediate, and eutrophic lakes have relatively low transparency and high concentrations of chlorophyll a and phosphorus. Due to the high chlorophyll concentration, restrictions are placed on the transmission of sunlight into eutrophic lakes -- especially on blue and red light that are absorbed in the upper waters of the lakes by microscopic algae. Generally green light penetrates furthest into such lakes, and although it can be used in photosynthesis, it is less efficient than red or blue light. Thus photosynthesis is more restricted to upper layers in eutrophic lakes than in less-productive lakes. Two additional major categories of lakes are dystrophy and mixotrophy. Lakes in these two categories have a high concentration of humic acids, and thus are heavily stained. Light penetration is severely restricted by the tea-colored stain, and only the red portion of sunlight is transmitted beneath the surface. Therefore, microscopic algae can grow only near the surface, and even then are light-limited (little or no blue light is transmitted to them). If such a lake has a low concentration of microscopic algae -- indicated both by algal counts (with a microscope) and by a low chlorophyll a concentration, the lake is called dystrophic. It is probable that the lake has a low input (loading) of nutrients, so that the microscopic algae are limited both by low light level and by low nutrient levels. However, if the lake receives a large loading of fertilizer, supplying an abundance of phosphorus, nitrogen and other essential nutrients, the microscopic algae may form a relatively concentrated community, and thus the chlorophyll a concentration rises. Such a lake is called mixotrophic -- a 'mixture' of organisms produced within the lake with imported organic material (mainly humic substances) from bogs or other sources outside the lake basin.

Plankton

Microscopic organisms found throughout the water column of lakes belong to the plankton, or plankton community. Members of the community are especially adapted for life in the open water where they must be able to resist gravity to stay in suspension, and to capture energy for survival. Important members of the plankton community are all microscopic, and belong to several different groups of bacteria, algae, fungi, and animals. In some cases the organisms spend their entire life in the open water, while in other cases only a fraction of their life (usually early stages, as in some insects). Students of biology are often attracted to the plankton community because of the immense diversity of organisms and processes that occur within it, because of its relative importance to a body of water, and especially because much about life of larger organisms can be learned from these special plankton organisms.

Interactions between the plankton community and lakewater determine to a very large extent the trophic status of lakes. In addition, a firm foundation is laid for the long-term management of lakes when the characteristics of the plankton community and the lakewater are determined.

Seasonal changes in both the plankters (members of the plankton community) and in the water chemistry require that several observations be made each year in a lake. Annual changes are generally slower, and can be discerned only during the course of long-term monitoring of principal parameters of plankton and water chemistry.

It is beyond the scope of this section of the report to describe all of the important changes that occur in the plankton as a lake passes through various trophic stages (oligotrophy, mesotrophy, etc.). But foremost among these is the change in concentration of plankton organisms -- especially the microscopic algae. This change is usually regulated by chemical loading into lakes, but is also regulated by seasonal changes in weather, and by several biological processes that occur in lakes -- such as grazing by microscopic crustaceans (water fleas and their allies). A good monitoring program includes not only an analysis of numbers of plankters, but also of types. Predictions of trophic evolution in lakes may be discerned more quickly by observing such changes in the plankton.

APPENDIX C

GLOSSARY

Aerobe	Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.
Algae	See phytoplankton.
Alkalinity	Total concentration of bicarbonate and hydroxide ions (in most lakes).
Anaerobe	Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.
Anoxic	Without oxygen. The hypolimnion of a lake may become anoxic if there are many organisms using oxygen for respiration and there is little replenishment from the atmosphere.
Benthic	Referring to the bottom sediments.
Bacterioplankton	Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many

specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate	The most important ion (chemical) involved in the buffering system of New Hampshire lakes.
Buffering	The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the main chemical responsible for buffering is the bicarbonate ion. (See pH.)
Chloride	One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.
Chlorophyll <u>a</u>	The main green pigment in plants. The concentration of chlorophyll <u>a</u> in lakewater is often used as an indicator of algal abundance.
Circulation	The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.
Density	The weight per volume of a substance. The more dense an object, the heavier it feels.

Low-density liquids will float on higher-density liquids.

Dimictic — The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy — The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll a concentration may be low or high.

Epilimnion — The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Holomixis — The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Eutrophy — The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi disk depth, high chlorophyll a, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO_2 — Carbon dioxide that is not combined chemically with lakewater or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Humic acids — Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are comsumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen ion — The ion which is measured to indicate acidity. (See pH).

Hypolimnion — The deepest layer of lakewater during periods of thermal stratifiction. (See lake diagram)

Lake — Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, lochs, billabongs, bogs, marshes, etc.

Lake morphology — The shape and size of a lake and its basin.

Meromixis — The condition where the entire lake fails to circulate to its deepest point; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy — The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a, secchi disk depth, and total phosphorus are also moderate. These lakes are esthetically 'fair' but not as good as oligotrophic lakes.

Metalimnion — The 'middle' layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree Celsius per meter depth. Also called the thermocline.

Mixis — Periods of lakewater mixing or circulation.

Mixotrophy — The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy — The lake trophic state where algal production is low, Secchi disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn	See circulation or mixis.
pH	A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times.
Photosynthesis	The process by which plants convert carbon dioxide into glucose (sugar) using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance.
Phytoplankton	Microscopic algae which are suspended in the 'open water' zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.
Parts per million	Also known as PPM. This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 PPM of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water.
Plankton	Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants.

Saturated — When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen.

Specific conductivity — A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum — A layer or a "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification — The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind. (See Appendix B.)

Thermocline — Region of temperature change. (See metalimnion.)

Total Phosphorus — A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic status — A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories, and Appendix B)

Z — A symbol used by limnologists as an abbreviation for <u>depth</u>.

Zooplankton — Microscopic animals in the planktonic community. Some are called 'water fleas', but most are known by their scientific names. Scientific names include: <u>Daphnia</u>, <u>Cyclops</u>, <u>Bosmina</u>, and <u>Kellicottia</u>.